TITLE: Introduction to Long-Term Biological Effects of Nuclear War

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SUMMARY:

This report summarizes the state of knowledge and concepts about the reaction of biological systems to effects of nuclear weapons under nuclear war conditions, about the likely extent of damage to agricultural and wildlife ecosystems under nuclear war conditions, and about the factors involved in the long-term recovery potential of these systems after damage. In the study, an attempt was made to organize the available information for objective discussion of the subject, to outline the state of the art regarding capabilities to use the information (as well as its availability), and to make estimates of radiological effects using the available data and available (or new) computational methods.

Within the reliability of the current information on the biological response of biological species to radiation exposures, the results of the study lead to the conclusion that long-term biological and ecological effects would not be so severe as to inhibit or seriously delay the national recovery after a nuclear attack similar to one of those assumed in the study. Rather, the major problems of population and biological resource survival are concluded as being associated with the short-term biological effects that would result from the exposure of all biological species to gamma radiation from fallout. The alleviation of these effects thus centers on the availability of shelter for the protection of the population and a local capability for organized efforts to recover food and water and other such resources that would be required to maintain the health of the survivors as a coherent work force in the early postattack period. This is the time period after attack when the need for knowledgeable leadership would be critical and when errors in recuperative actions would be the most likely to lead to secondary fatalities.

For several assumed types of nuclear attack, the effects of the radiation from fallout in some areas of the country could result in fatal doses to all higher forms of life in exposed conditions. A few percent of the total land area of the country would likely be denuded of vegetation for a short period of time. However, the location and extent of these areas, with respect to other aspects of resource damage and economic recovery problems, are such that the ecological consequences of the biological damage in these areas could have little or no influence on national recovery. Essentially all of the economically important agricultural land is recoverable within the first year after attack for the case in which the existing shelter system is used.

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Because of the differences in volatility among the various fission-product elements, fractional condensation would be expected to occur throughout the fallout formation process. The significant radiological property associated with the amount of a radioelement that condenses during the second period of formation is that the fraction condensed is considered to be potentially soluble and biologically available for assimilation by plants and animals. The more volatile radioelements in fallout, in fact, have been found to be most soluble and more biologically available than are the refractory elements. However, the fractional degree to which each element condenses in either period of condensation is expected to depend very much upon the temperature at which diffusion into the particle becomes limiting and the condensing radioelement is concentrated in the surface layer of the particle.

If all the materials that were produced in a land-surface nuclear detonation and all that entered the fireball volume remained together for the first 5 or 10 minutes after detonation, the radioactive compositions and the subsequent radioactive decay (and nuclide solubility) would be about the same for all fallout particles. However, it is known that all the entering particles do not remain together in the fireball and cloud for such periods of time. Immediately after the fireball expands to maximum size, it begins to rise in the air. The upward motion of the hot gases sets in motion a large-scale toroidal circulation because of the drag forces of the surrounding air. This toroidal motion, with circulation velocities in excess of 100 miles per hour, is probably responsible for pulling blast-loosened soil from the crater and crater lip into the rising fireball.

The circulation of the particles in the toroid should result in an earlier separation of the larger particles from the circulating volume(s) of condensing gases and should, by centrifugal forces, move them to the periphery of the toroid. When the circulating particles reach the periphery (or the bottom) of the cloud and the pull of gravity begins to exceed the upward drag forces of the air near the base of the rising cloud, the particles begin falling to earth. Other particles of the same size, not yet near the periphery of the toroid, may continue to circulate for a much longer time before they leave the base of the cloud. These views of particle circulation and formation are supported by (1) the relatively long period over which particles of a given size arrive on the ground, (2) the relatively early arrival times for close-in fallout, (3) the variation in composition of the radioelements on particles of different sizes, and (4) the variation in specific activity and radioelement composition among particles of a given size.

The concentration of the volatile radioelements in the radioactive compositions carried by the larger particles is generally found to be low. This lower relative concentration could occur only through the earlier ejection of the large particles from the volume of the fireball containing the radioelements (vapors plus small vapor-condensed particles). In addition, the large fallout particles from many low tower detonations do not contain or carry any soluble radioelements, and, therefore, these

particles must have been ejected when their surfaces were still at a very high temperature. Thus the toroidal motion is considered to be partially responsible for the observed differences in the gross radioactive decay and biological availability of different radioelements carried by fallout particles with different diameters.

The toroidal motion which apparently causes early ejection (early with respect to fall from the stabilized cloud) of the larger particles also can cause prolonged apparent buoyancy of the smaller particles. The latter would circulate for longer times and, after cooling, would remain in the volume to collect the more volatile elements on their surfaces. Except for the fallout particles with diameters less than about 50 to 80 microns, all appear to leave the cloud volume under influence of circulation.

Observed data on the properties of fallout from detonations on soils similar to those of likely targets in a nuclear war are nonexistent. In fact, only a few detonations in both the Eniwetok Proving Ground and Nevada Test Site have provided useful data for the development of fallout models for land-surface detonations. The large yield devices were all detonated over water, on coral atolls, or in the air. No evidence exists today for proving that all types of information on fallout obtained from these few weapons tests are satisfactory for use in developing reliable models that are designed to give quantitative estimates of the properties of fallout (and its distribution) from assumed detonations of high yield weapons on targets in the continental United States. Perhaps continued theoretical developments and concurrent supporting high temperature experimental work are the only remaining methods for improving and evaluating the validity of some of the input data for currently available fallout models.

The radionuclides in worldwide fallout are generally found to be quite soluble, and all the radionuclides are, to a large degree, biologically available. However, a fairly large number of fused-type particles are formed from the warhead or bomb materials as identified in stratospheric collections of bomb debris.[3] A large fraction of the worldwide fallout from a large-yield nuclear air explosion appears to be formed in the stratosphere at some time after the detonation through processes of coagulation and coprecipitation of the radioactive atoms with the natural stratospheric aerosol particles. The latter, composed mainly of water-soluble ammonium sulfate compounds, then serve as carrier particles for returning the radioactive debris to earth.

In all types of detonation conditions, the form and properties of the produced fallout are determined during the cooling period of the fireball and cloud, as well as at later times for the decay products of gaseous radioelements and for many other radioelements in airbursts that produce the worldwide fallout. The materials that enter, or are in, the fireball at these times are important factors in determining the properties of the fallout particles. These formation processes set the stage for all subsequent radiological interactions between the fallout materials

and the biological and ecological environment in which the materials are deposited.

One of the chief difficulties in the prediction or computation of levels of fallout at a given location, in addition to the problems of defining the fallout particle cloud source discussed above, is the analysis and prediction of the wind structure as the major influence in distributing the fallout particles over the earth's surface. Other major factors for which very little accurate data exist, especially for fallout from large yield detonations over silicate soils, include (1) the variation of the specific activity with particle size and (2) the influence of the environmental material (soils and other likely target materials) on the gross particle-size distribution of the fallout (i.e., by particle number, mass, or radioactivity content).

A comparison of several currently used fallout models (or fallout pattern scaling systems) is shown by the relative areas within stated fallout radiation rate contours in Table 1. The differences in the areas enclosed by stated standard intensity contours among the various computing systems for the two weapon yields and wind conditions are generally not small. Assumptions regarding the fraction of the gross fallout activity on particles of a given diameter and the locations of the particles in the initial cloud source are likely major causes of the differences among the models.[2] The integrated activity in the fallout patterns within the 1 r/hr at 1 hr contour, for the two cases of Table 1, gives the following values for the radiation rate conversion factor (in r/hr at 1 hr per KT/sq mi):

Case A: WSEG-RM10 - 1,500
ENW - 1,460
Anderson - 1,550
SFSS - 1,430

Case B: WSEG-RM10 - 2,500
AFCIN - 800
WB - 2,000 (approximately)
WSEG-NAS - 2,400

For Case B, the theoretical value of the conversion factor for unfractionated fission products is 3,600.[2] The parameters and data relating to the evaluation of the conversion factor from measured quantities on the fallout from Shot Small Boy in Operation SUN BEAM are discussed in Reference 8.

Four additional types of radiological hazards to biological species, in addition to the more general external hazards from gamma radiation, are known. These are (1) the contact hazard, (2) the inhalation hazard, (3) the beta-field hazard, and (4) the internal hazard from ingested radionuclides.

Table 1

RATIO OF AREAS WITHIN STATED STANDARD INTENSITY CONTOURS FOR FALLOUT PATTERNS COMPUTED FROM VARIOUS MODELS RELATIVE TO THOSE FROM THE WSEG-RM10 MODEL[a,b]

Model Designation	Standard Intensity (r/hr at 1 hr) 1	10	100	1,000
	Case A. 10-MT yield, 15 mph wind speed (100 percent fission)			
ENW (1957)[5]	8.66	1.86	0.70	0.62
Anderson[6]	1.40	1.14	1.00	0.96
Simple Fallout Scaling System[2]	0.67	0.71	0.83	1.10
	Case B. 1-MT yield, 25 mph wind speed, 0.2 knots/10^3-ft vertical shear (100 percent fission)			
AFCIN[7]	0.15	0.18	0.26	0.57
WB (1962 ENW)[7]	2.16	1.18	0.67	0.40
WSEG-NAS[7]	1.96	1.36	0.87	0.60

a Standard intensities calculated from WSEG-RM10 Model were first multiplied by 0.56 to account for terrain shielding and instrument response for the 10-MT-yield weapon fallout pattern

b From Reference 4

Table 3

FRACTION OF SR-90 IN THE RUNOFF WATER FROM CROP LAND[a]

Crop	Fraction of Deposited Sr-90 in the Runoff Water	Fraction in the Runoff Water per Inch of Rainfall	Runoff Water (inches)
LaCrosse, Wisconsin; 16 percent slope; March-August 1957; Fayette silt loam			
Corn	0.045	0.0020	0.93
Oat	0.041	0.0018	1.25
Clover[b]	0.0035	0.00016	0.15
Tifton, Georgia; 3 percent slope; March-December 1957; Tifton loamy sand			
Corn	0.014	0.00034	1.32
Oat[b]	0.0044	0.00011	0.37
Peanut	0.014	0.00035	1.20

a From Reference 21

b Ground cover established before the measurements were started

Table 6

RESPONSE OF ANIMALS TO BRIEF EXPOSURES IN EXTERNAL GAMMA RADIATION FIELDS IN TERMS OF THE LD_{50} IN 30 DAYS[a]

Species	$LD_{50}/30$ (roentgens)
Dog	280
Guinea pig	340
Goat	350
Mouse	440
Swine	510
Sheep	520
Cattle	540
Rat	640
Burro	650
Monkey	760
Rabbit	800
Poultry	900

a From References 11, 28, 29, and 30: the listed $LD_{50}/30$ values were used in the calculations described in this report. Other $LD_{50}/30$ values, differing from those listed by as much as a factor of 2, are reported in References 93, 94, and 95. Some of these are: dog, 319; sheep, 360; burro, 375; swine, 390; rat, 936; and mouse, 940. The basic causes of these differences remain to be clarified.

Table 7

LD_{50}/30-DAY DOSES FOR BRIEF EXPOSURES OF FISH AND SHELL ANIMALS[a]

Species	$LD_{50}/30$ Days (rads)
Adult fish	1,000- 2,000
Crustacean	800-100,000
Mollusc	4,000-500,000

a From Reference 11

Some of the easily observable biological responses of plant parts (all parts exhibit response) are: (1) roots--reduction of growth and inhibition of new root formation; (2) stems--dwarfing, excessive branching, local swelling, fasciation, formation of adventitious roots, and tumor growth; (3) leaves--reduced blade development, dwarfing (asymmetrical blades), abnormal veination, decrease in chlorophyll (discoloration), and change in texture (older leaves become dry, brittle, and coarse and young leaves thicken and become leathery); and (4) buds and flowers--retarded formation, reversion to vegetative growth, fasciation, and changes in color and form.

Notable changes in plant growth habits after exposure to critical doses of radiation include the early dropping of leaves (deciduous trees) and the retardation of bud and new-shoot formation. The reduction in reproductive capability after exposure is related to the effect on vegetative growth (plant vigor), the retardation of flowering, and the direct damage to the parts of the cells that participate in the reproductive cycles of the plant.[32] The extreme combination of all the various radiation damage manifestations results in death of the plant.

The relative radiosensitivity of plants ranges over a factor of at least 5,000 from algae and bacteria, which are the most resistant or least affected by radiation, to the gymnosperms, which are among the most radiosensitive of the plants. Among the higher plants, the range in chronic, or protracted, doses to produce a similar biological response is the order of a factor of 500.

The reduction of vegetative growth of plants after exposure to nuclear radiation is apparently caused mainly by a reduced rate of cell division; since reduced growth is usually the first gross observed effect of the exposure, it is believed that the apical meristem regions are highly radiosensitive.[32] The radiosensitivity of young growing plants is probably highest.[33] Growth retardation appears to have a threshold dose; much of the plant growth retardation data can be represented by a function of the form

$$G = G_o \exp\left[-k_D(D - D_o)\right] \tag{1}$$

where G is the growth characteristic for an exposure dose of D roentgens, G_o is the characteristic for the controls (zero dose), D_o is the threshold dose, and k_D is a growth retardation coefficient. Some values of k_D and D_o for different plant species, as derived from reported data, are shown in Table 8.

Basic relationships between plant cell nucleus characteristics and radiosensitivity recently have been derived by Sparrow and Woodwell[32] from correlations between these characteristics and data on the response of plants to external gamma radiation. The cell nucleus variables include (1) cell nucleus or chromosome volume, (2) cell nucleus DNA content,

Table 8

ESTIMATED PLANT RETARDATION THRESHOLDS
AND GROWTH RETARDATION COEFFICIENTS
FOR SOME PLANTS EXPOSED TO GAMMA (AND X) RADIATION[a]

Species	Response	k_D (roentgens^{-1})	D_o (roentgens)	Time of Total Exposure
Pinus strobus (seedlings)	Leader length growth	4.6×10^{-4}	910	15 months
Taxus med. cv. hatfieldii	Number of growth buds	1.3×10^{-3}	850	12 months
Quercus alba	Number of leaves	2.3×10^{-4}	5,500[b]	6 months
Pinus regida	Terminal growth	-	360	6 months
Quercus alba	Terminal growth	-	1,800	6 months
Wheat (seedlings)	Growth[c]	-	250[c]	acute dose

a From References 32, 33, 34, and 35

b Cs-137 source; unmarked numbers are for Co-60 source

c Maximum growth retardation occurred for exposures at 2 days after germination; X-radiation

Table 9

PLANT RESPONSE RELATIVE TO MORTALITY (LD_{100})
OF HERBACEOUS ANNUALS FOR CO-60 GAMMA RADIATION[a]
(Exposure Times from 8 to 12 Weeks)

Response	Fraction of LD_{100} Dose Rate
Normal appearance	0.11
10 percent growth reduction	0.26 ± 0.02
Failure to set seed	0.31 ± 0.06
50 percent growth reduction	0.34 ± 0.04
Pollen sterility (100 percent)	0.41 ± 0.04
Floral inhibition or abortion	0.44 ± 0.04
Growth inhibition (severe)	0.58 ± 0.03
LD_{50}	0.75 ± 0.02
LD_{100}	1.00

a From Reference 32

Table 10

SINGLE ORAL INGESTION LEVEL OF SEVERAL RADIONUCLIDES
BY ADULT SHEEP CAUSING SERIOUS INJURY OR DEATH[a]

Radionuclide	Ingestion Level (atoms ingested/kg body weight): Serious Injury[b]	Ingestion Level (atoms ingested/kg body weight): Lethal ($LD_{50}/30$)
Sr-90	4.7×10^{16}	4.7×10^{17}
I-131	7.4×10^{12}	5.6×10^{14}
Cs-137	2.5×10^{16}	2.5×10^{17}

a From Reference 11
b Type of injury not specified

Table 11

ESTIMATED RADIATION EXPOSURES FOR LIKELY RECOVERY OF TYPICAL ECOSYSTEMS[a]

Major Ecosystem	Exposure Dose for No Significant Effect (roentgens)	Exposure Dose for Likely Recovery (roentgens)	Exposure Dose for Likely Recovery in about 2 Years (roentgens)
Typical farmland	200	200	-
Coniferous forest	200	200 — 2,000	2,000
Deciduous forest	200	200 — 10,000	10,000
Grassland	2,000	2,000 — 20,000	20,000
Herbaceous successional	4,000	4,000 — 70,000	70,000

a From Reference 43

External Contamination of Plants

The external contamination of plants by local fallout particles is discussed in detail in References 9 and 10. The major portion of the currently available data on the subject was obtained in the Costa Rican experiments; however, in this described study, which was initiated prior to the Costa Rican work, the plant contamination factors that were used were those derived from the field test data, as shown in Figure 3. In the model, the average effect of weathering on the foliar deposits was assumed to be represented by

$$a_L = a_L^o e^{-0.05(t-\bar{t}_a)} \tag{7}$$

where a_L is the contamination factor in terms of the ratio of the activity or weight concentration of the fallout on the foliage to the surface density of the fallout, and $\bar{t}_a$ is the average time of arrival of fallout. The factor, 0.05, corresponds to a weathering half-life of 14 days, as discussed in References 9 and 50. Newer data on the effect of wind and rain on foliar contamination indicate that weathering effects, in general, do not correspond to that given by Equation 7; however, the computations of this study were made using Equation 7 and therefore underestimate, to some degree, the contamination levels on most food crops due to the contamination of the foliage by local fallout. The initial values of the contamination factors, $a_L^L (\approx a_L^o)$, used in the calculations are summarized in Table 12.

Entry of radioactivity from worldwide fallout into plants is made via two major routes: (1) direct foliar absorption of radionuclides in solution in rain and (2) root uptake from the accumulated nuclides in the soil. Measurements of the total specific activity of the edible parts of plants therefore represent the sum of both modes of entry, and the problem becomes one of separating the total into parts. There are many data available on root uptake from pot experiments so that it would appear that a reliable approach would be to subtract that amount of activity due to root uptake from the soil. The usual result, however, is that all or more of the observed activity is accounted for by root uptake alone. It would therefore appear that the uptake of crops grown in the field is different from that of crops grown in pot experiments.

Among the reasons for such differences, aside from the usual uncertainty in the number of atoms (such as Sr-90) per unit area of soil, are the effects of distribution in depth in relation to root habit and the long-term availability of the nuclide in question. The method usually followed in assessing foliar and root uptake from worldwide fallout is to set up an equation with two unknowns and solve these over successive years.[51,52] This method, for any nuclide, is represented by

Figure 3

EXPERIMENTAL VALUES OF a_L

AS A FUNCTION OF a_o FOR A 15 MPH WIND SPEED

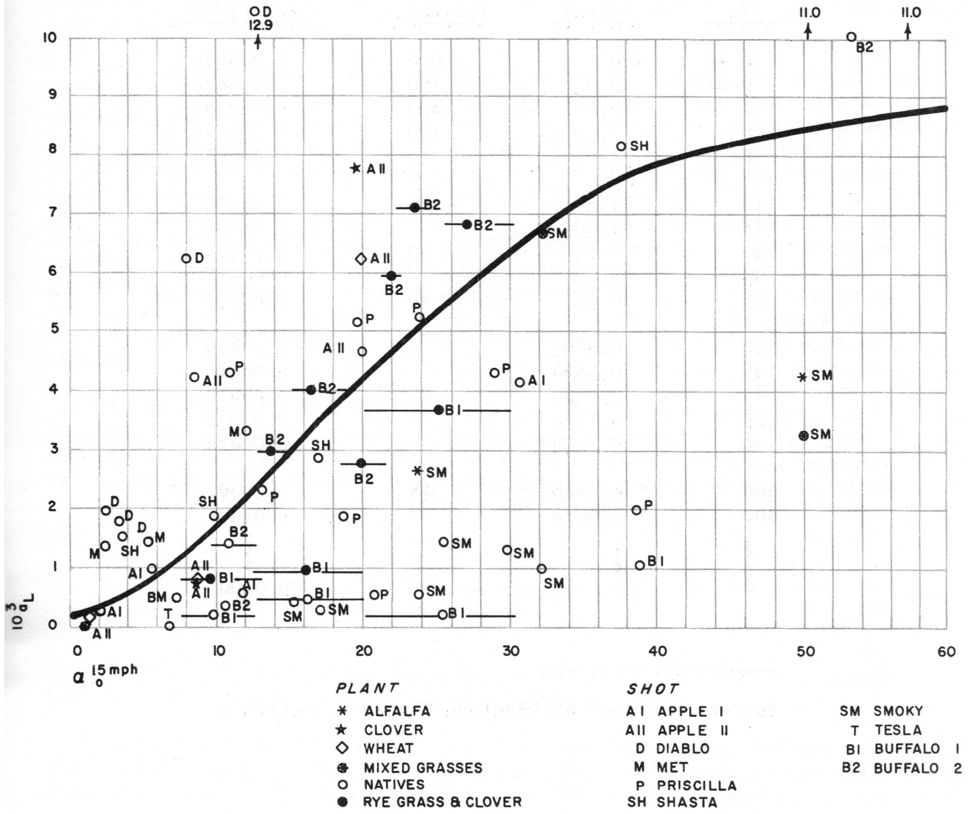

Table 12

FOLIAR CONTAMINATION FACTOR VERSUS α_o^{15}
AND RELATED PARAMETERS

α_o^{15}	Particle Falling Velocity v_f^o (mph)	Particle Diameter d (microns)	Foliar Contamination Factor a_L^L (sq ft/gm)
0.15	100	8,000	0.000200
0.50	30.0	1,170	0.000225
1	15.0	500	0.000250
5	3.00	120	0.000750
6	2.50		0.000930
10	1.50	75	0.00170
15	1.00		0.00300
20	0.75	50	0.00425
25	0.60		0.00535
30	0.50	40	0.00635
35	0.4286		0.00720
45	0.3333		0.00815
75	0.2000	25	0.00912
100	0.1500		0.00945
150	0.1000		0.00975
300	0.0500	13	0.00997
400	0.0375		0.0100
↓	↓		↓
∞	0	0	0.0100

Source: Derived by Stanford Research Institute

Table 13

ESTIMATED VALUES OF a_L^w FOR SELECTED CROPS AND RADIONUCLIDES

Crop	a_L^w $\left(\frac{10^{-5} \text{ atoms/gm dry weight}}{\text{atoms/sq ft soil}}\right)$ Sr-89, Sr-90	Zr-95, Ce-144	Ru-106	Cs-137
Corn	90	0.1	0.3	40
Sorghum	90	9.0	27	450
Wheat	90	9.0	27	425
Oat	90	9.0	27	450
Barley	30	3.0	9.0	180
Dry bean	20	2.0	6.0	800
Soy bean	20	2.0	6.0	240
Alfalfa	600	600	600	600
Clover	700	700	700	700
Potato	1	0.1	0.3	100
Green pea	6	0.6	1.8	18
Sugar beet	1	0.1	0.3	100
Tomato	500	500	500	1,750
Snap bean	20	2.0	6.0	60
Cabbage	300	300	300	1,050
Dry Onion	1	0.1	0.3	100
Carrot	1	0.1	0.3	100
Lettuce	500	500	500	1,750
Apple	50	5.0	15	150
Peach	300	30	90	900
Orange	50	5.0	15	150

Source: Stanford Research Institute

Exposure of both parents to 700 roentgens would increase the stillbirths and early childhood deaths from the present 5 percent to 7 percent in the first generation. If the entire population was exposed to 700 roentgens, one additional stillbirth or early childhood death per conception by the originally exposed parents could be expected over many generations.

Infant mortality in the first year of life would increase from 26,000 to 29,000 per million parents in the first generation if both parents are exposed to 700 roentgens. If the entire population is exposed to 700 roentgens, infant deaths could be expected to increase by 91,000 per million originally exposed parents over many succeeding generations.

If both parents are exposed to 700 roentgens, major defects in newborn infants could be expected to increase from the present 2.5 percent to about 3.2 percent. If the entire population were exposed to 700 roentgens, 210,000 additional birth defects could be expected per million live births in the first generation. Unfortunately, no data are available for estimating the genetic effects that might result from mixed doses (e.g., one parent being exposed to 700 roentgens and the other having no exposure).

Gut Response, Internal Emitters

Absorbed Dose (rads)	Response
100	Threshold for nausea, vomiting
1,000	Threshold for tumor production
1,300	Threshold for acute radiation injury

In the cases considered in the third section of this report, the absorbed dose to the lower large intestine was well below the threshold for nausea and vomiting.

Thyroid Response, Internal Emitters[a]

Absorbed Dose (rads)	Response
10,000 ± 6,000	Threshold for hypothyroidism
80,000 ± 20,000	Central destruction of thyroid
150,000 ± 50,000	Complete destruction of thyroid

a For adult humans. Infant thyroids are more highly susceptible to damage; threshold exposure dose for carcinoma in the thyroid of children and young adults for a brief exposure is about 200 roentgens.

Table 28

FRACTION OF GROSS FOLIAR CONTAMINATION
FROM LOCAL FALLOUT ASSOCIATED WITH EDIBLE PLANT PARTS

Crop	f_p [a]
Sweet corn	0.005
Sorghum grain	0.005
Wheat	
Grain	0.005
Flour	0.001
Oat	
Hay	0.5
Grain	0.005
Barley	0.005
Dry bean	0.005
Soybean	0.005
Alfalfa	0.5
Clover, timothy, and other hay	0.5
Potato	0.01
Green pea	0.005
Sugar beet	0.01
Tomato	0.01
Snap bean	0.005
Cabbage	0.05
Dry onion	0.01
Carrot	0.01
Lettuce	0.05
Apple	0.01
Peach	0.06
Orange	0.01

a All nuclides

Table 31

GAMMA RADIATION SENSITIVITY OF PLANTS

Common Name	7-Day Lethal Dose (roentgens)
Grains	
Corn	7,500
Sorghum	(7,500)[a]
Wheat	10,000
Oat	25,000
Barley	(20,000)
Field Crops	
Dry field and seed beans	12,000
Soybean	12,000
Alfalfa	50,000
Clover and timothy	25,000
Irish potatoes	4,500
Tobacco	50,000
Green pea	10,000
Sugar beet	(12,000)
Tomato	3,000
Sweet corn	7,500
Snap bean	(5,000)
Cabbage	50,000
Dry onion	5,000
Carrot	(5,000)
Lettuce	12,000
Pasture	7,500
Trees	
Apple	(5,000)
Peach	(5,000)
Orange	(5,000)
Loblolly pine	7,500
White pine	7,500
Hickory	< 30,000
White oak	> 50,000
Black oak	> 50,000

a Values in parentheses are estimated values (also indicate plant species for which no response data have been reported); the estimates were made using the assumption that similar species have similar responses to a given radiation dose.

Table 34

BODY AND ORGAN DOSES IN REMS TO ADULT HUMANS
FOR INGESTION OF 1 LITER OF WATER PER DAY
FROM THE 1ST AND 7TH DAY TO THE 30TH AND 91ST DAY AFTER THE HM ATTACK
FOR FIVE REPRESENTATIVE CITIES[a]

City	t_o / t [b]	Total Body 1	Total Body 7	Bone[c] 1	Bone[c] 7	Thyroid 1	Thyroid 7	Lower Large Intestine 1	Lower Large Intestine 7
St. Louis	30	5.41	2.95	21.8	16.1	6,950	3,440	88.1	60.5
	91	10.85	7.57	80.6	65.6	9,550	5,670	144	116
Philadelphia	30	0.348	0.190	1.41	0.971	445	220	5.71	3.9
	91	0.701	0.490	5.11	4.11	611	364	9.34	7.56
Baltimore	30	0.0373	0.0205	0.155	0.108	47.3	23.4	0.612	0.420
	91	0.0767	0.0539	0.574	0.463	64.9	38.6	1.009	0.815
Boston	30	0.00553	0.00869	0.0228	0.0157	7.03	3.47	0.0911	0.0641
	91	0.01129	0.00792	0.0856	0.0691	9.64	5.74	0.151	0.122
Tulsa	30	0.000509	0.00028	0.00214	0.00149	0.642	0.418	0.0084	0.00575
	91	0.00109	0.000743	0.00816	0.00659	0.881	0.525	0.014	0.0113

a Dose conversion factors taken from Reference 38
b Time in days
c Dose to total bone; does not include contributions from La-140 (daughter of Ba-140)

Figure 6
FOREST SURVIVAL FROM THE HM ATTACK

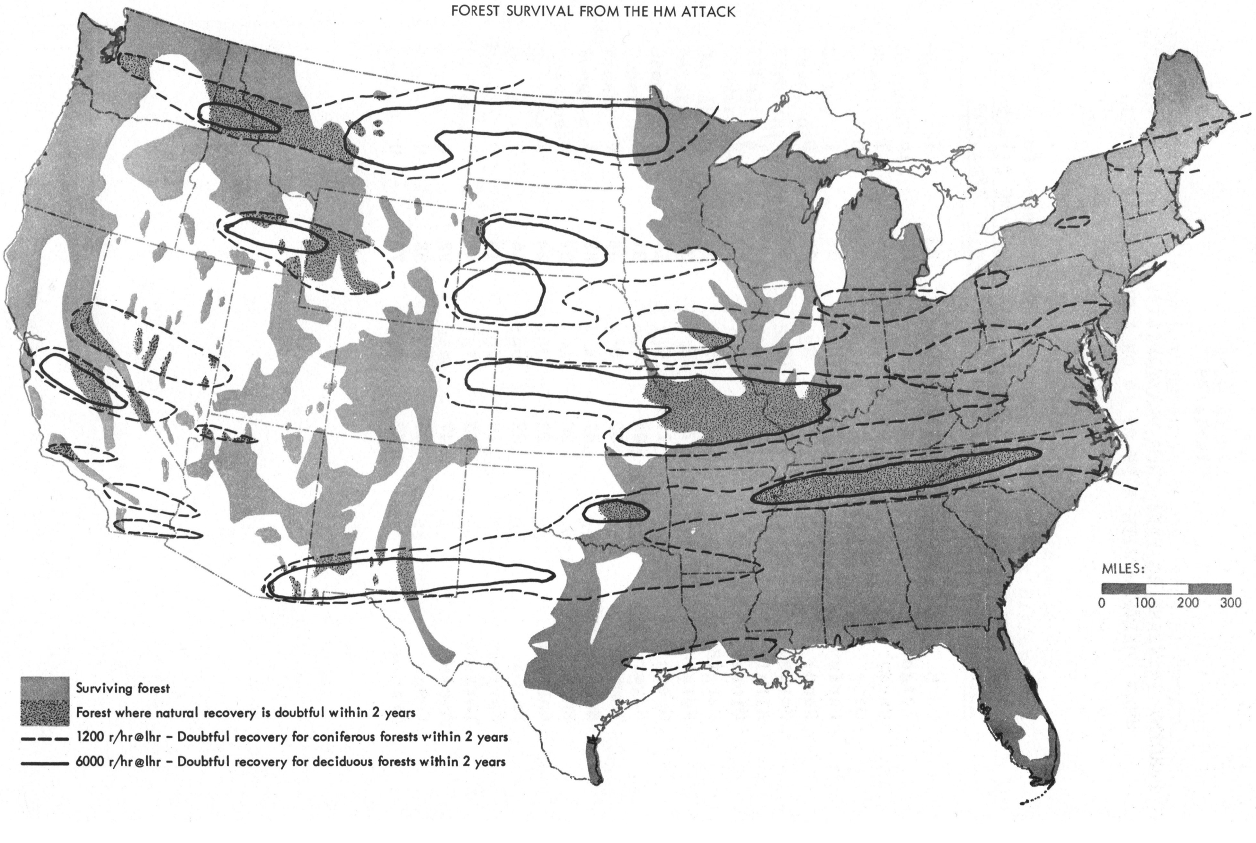

Table 50

POSTATTACK PRODUCTION POTENTIAL PER CAPITA
(Values in Percent of Normal)

Crop	HM Attack Existing Shelter	HM Attack Good Shelter	MC Attack Existing Shelter	MC Attack Good Shelter
Corn	92	92	92	97
Sorghum	140	95	93	100
Wheat	88	84	80	92
Oat	102	99	92	99
Barley	88	88	72	95
Bean, dry field	112	102	112	101
Soybean	130	98	101	97
Alfalfa	99	101	94	100
Hay	98	100	93	100
Potato	99	76	86	82
Green pea	146	104	114	101
Sugar beet	106	87	90	92
Tomato	131	85	109	98
Sweet corn	127	102	108	100
Snap bean	159	101	114	101
Cabbage	164	104	114	101
Onion	144	97	108	98
Carrot	171	104	105	101
Lettuce	171	102	114	101
Apple	117	93	106	97
Peach	112	84	111	99
Orange	126	88	114	101
Bull, steer, and calf	85	51	83	74
Milk cow	94	56	93	83
Swine	78	47	85	76
Sheep	106	66	91	81
Chicken	101	60	94	84

MEASURING MILITARY EFFECTS OF NUCLEAR WEAPONS

A Manual for the Conduct of Full-Scale Field Tests

Compiled
by

STANFORD RESEARCH INSTITUTE
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for

Field Command, Armed Forces Special Weapons Project

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half-way measures are not successful. Most electromechanical systems will tolerate rigid mounting to shelters under most typical conditions. Experience at Nevada Test Site shows that a typical concrete instrument shelter, buried and with 1 to 5 feet of earth cover, will suffer a peak acceleration (in g units) of 1/8 to 1/4 the peak overpressure (in psi) recorded at the ground surface over the shelter. This ratio applies in regions of moderate overpressure (less than 15 psi) where the pressure-time waveform is classic; in precursor regions, the ratio may be 1/10 or less.

In Nevada, the very dry and porous soil of the test areas is characterized by high attenuation of the transmission of ground phenomena (Reference 16). For rules of thumb in predicting free field ground motion at a particular station at NTS, a useful expression for acceleration (from which velocity and displacement may be derived) is

Acceleration (g units) = KP,

where

P = overpressure, psi

K = proportionality factor between acceleration and overpressure

At NTS, at 5-foot depth, K = 0.3 - 0.6.

This same expression may be used for EPG; at the surface (above the water table), K = 0.5 to 1/5; and at 10-foot depth (below the water table), K = 0.05 to 0.15 (Reference 17).

17. Ground Motion Produced by Aboveground Nuclear Explosions: Part I Predictions; Part II Summary and Correlation of Data, SRI Project SU-2206, for AFSWC, Interim Technical Report No. 1, May 15, 1958 (SRD)

nected cells, and is waterproof. In applying it, be sure to give it expansion room.

Pop-up field radiation survey meters used on Plumbbob, although protected from direct blast and thermal effects by being placed underground, appeared to be affected considerably by ground shock; and in future similar applications would be shock mounted.

Some agencies believe that commercial equipment which is inherently less rugged than military versions withstands ground motion better than the comparatively rigid military equipment.

Finally, the occurrence of airblast-induced water waves at EPG has been the concern of some experimenters in the past. At present, SIO is revising its scaling law for water waves in the lagoon (Reference 18). The result will, it is hoped, give answers within a factor of 2. In the main, the concern is the protection of installations which must be subjected to the blast-induced waves from previous shots; sometimes the water wave effects from other (larger) shots are more severe than similar effects from the shot for which the equipment is installed.

THERMAL RADIATION

The thermal radiation from a nuclear explosion, in addition to its importance as a primary parameter, is used a great deal as a triggering mechanism for other instrumentation, e.g., blue-box and FIDO (see Chapter 7). However, some precautions are necessary to minimize the undesirable aspects of thermal disturbances (Reference 7).

A rule-of-thumb for estimating thermal energy, neglecting atmospheric attenuation, is 1 calorie/cm^2/kt at one mile. The energy is then proportional to yield and inversely proportional to the square of the slant range.

A useful material for thermal shielding is aluminum; it can be obtained in the form of foil and tape. Thermal shielding is necessary for such things as multi-conductor cables, dosimeters, thin glass, plastics, and mechanisms incorporating temperature-sensitive fluids or greases. (Heavy glass has held up at high pressure and thermal levels when it has been used as a blast shield in thermal measurements.) In regions receiving in excess of 15 calories/cm^2 radiant exposure, diaphragm-type strain gage transducers must be shielded.

If you are using aluminum foil close in to protect a painted surface, which you intend to use as a station on recovery, the blast wave may remove the foil before the thermal phase is over and your painted surface will be burned off. In fact, close in, the thermal phase for all considerations, continues long past the blast phase.

Another satisfactory shield is the use of a window shade asbestos curtain.

If you have placed numbered samples in the field, be sure to turn the numbered side away from the bomb light; also black numbers on flammable material will burn through.

White paint is also satisfactory as a thermal shield, especially on water borne gear that may be damaged by wind and waves prior to shot time.

Beware of canvas tarp ignition and fire, if you wish to use it to cover a station; usually the blast wave "blows out" small fires, but a smoldering tarp has been known to cause trouble. If you choose to use sandbags for cover close in, the bags should be covered with a cement slurry to prevent fire.

For triggering devices which make use of the thermal for their operation, it may be desirable to separate the sensing element from the control circuit (Example: separate photocell from the blue-box relays); in this way, it is possible to protect the control unit more effectively from deleterious environmental effects.

ELECTROMAGNETIC (EM) PULSE

In the field of weapons effects testing, if anything approaches the mystic realm, it is the effect due to the transient electromagnetic pulse (sometimes called the induction signal) which occurs a few microseconds after zero time. This pulse has been harassing investigators almost since the beginning (Crossroads) and, sad to say, not much progress has been made in licking the problem although recently greater effort than before has gone into investigating this phenomenon (References 19, 20). The signal, which is confined to a frequency range of a few kc, affects most severely the electrical and electronic components used in instrumentation. Most of the lost data can be traced to transducer inductance coils, transformers, or recording galvanometer coils being short-circuited to ground at an early time (References 21, 22, and 23).

Characteristics

In general, the magnetic component of the EM signal has its largest value in the azimuthal "transverse" direction, as if the field emanated from a vertical electric dipole. Fairly strong components exist in the radial and vertical direction that are almost an order of magnitude weaker and possibly have a different origin. The signal drops off with distance, at a rate of at least $1/r^2$ or possibly as high as $1/r^3$. The fields are reduced to less than 1/10 magnitude of peak value within 100 msec, but weak signals may last for several milliseconds.

For projects measuring blast and shock, the most effective protective measure is to "float" or ground the system before zero time, and then have the blue-box (thermal pulse) signal close a relay which makes the system operative--after the electromagnetic transient has dissipated and before the blast wave has arrived. Still another method which has been used successfully is to connect the transducer case (local ground) to the cable shield (system ground) through neon tubes; also the transducer drive and output leads are coupled to local ground through neons.

For most thermal and prompt nuclear radiation measurements such a scheme would be unacceptable because many of the interesting features of the measurement occur in the first few milliseconds. For these Faraday and/or magnetic (iron or steel) shields have been used to protect instrumentation in underground shelters from the electromagnetic signal (see, for example, Reference 24).

In general, it appears wise to avoid electrical loops wherever possible; most projects ground their instrument cables at the recorder (or transducer) end only, which apparently minimizes the transient effect. Deeper cable trenching has been tried with questionable results. Cable lengths up to 12,000 feet have been used successfully. Although transient trouble has been experienced with conventional wire strain gages, recent flashover techniques have proven successful (Reference 25).

Piezoelectric gages, commonly used for small charge explosions, have been found unsatisfactory for measurements on nuclear explosions (except when used underwater for air or underwater bursts) owing mainly to excessive sensitivity to the transient EM signal.

Central Station and Gage Protection

From the standpoint of the blast and shock effects experimenter, the electromagnetic disturbance at zero time masks no data of importance directly. It is short in duration (not over 5 to 10 msec), whereas most effects of interest begin after 30 to 60 msec from zero time. However, it is prone to damage or paralyze equipment, causing serious loss of data.

Two areas of damage may be considered: (1) central station equipment, and (2) transducer and associated equipment. In general, the central station equipment is at a larger ground range than the transducer, with cables up to several thousand feet long running approximately radially between the two. The signal is also observed, but not so strongly, on cables extending outward from the central station.

Central station damage may take several forms, dependent on the type of equipment. It may consist of burned-out galvanometers or input transformers. It may only consist of overloading or overheating of non-linear elements (ring modulators, etc.), which results in zero shifts or changes in sensitivity without complete loss of data but with serious effects on accuracy. In any case, the effect appears to be due to a large transient flow of current between cable conductors and ground, not usually a flow between balanced conductors. When long cables are used, and no protective measures taken, the loss of data due to central station damage has on occasions been severe (20 to 60% of total).

Transducer damage is a different problem. All cases appear to show evidence of being caused by flashover to (local) ground, either within the transducer element, or at some other point which may cause unbalanced currents to flow and damage the transducer element. There is no evidence of damage due to currents induced in balanced lines.

Central station protection consists of simply grounding the signal lead during zero time. Most channels use a "half-bridge" circuit and a three-wire cable. Two of these wires are connected to a carrier oscillator output transformer whose center tap is grounded. For complete protection, each outer terminal of this transformer is connected to ground through a 2-mfd condenser, al-

though the necessity of these condensers is not proven. The third, or signal lead, is permanently connected to the signal input circuit, but is shunted to ground through a contact of a multi-contact relay. (Several 24-pole normally-open relays are required for large installation.) The relays are actuated a few seconds before zero time. A blue-box signal (two boxes are used for safety) de-energizes the relays through a secondary relay which provides a few milliseconds of delay. Thus the disturbing currents are shunted to ground during the crucial period, but the circuits are restored to normal well before the arrival of any signals pertinent to blast and shock phenomena.

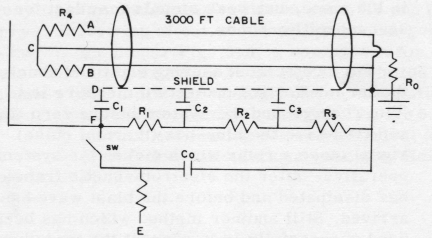
It must be realized that any system such as this introduces the hazard of gross loss of data in case of malfunction. Extreme care must be used in proving its reliability, and it should only be used where probability of damage by the electromagnetic signal is high.

Gage damage has not been significant with balanced-reluctance gages such as the Wiancko or similar devices. The most serious trouble has been permanent grounding of one circuit by the flashover, causing disturbances on other traces. None of these damaged gages was among those nearest ground zero.

When resistance-wire strain gages were used, the record is much poorer, and reports by all agencies show an important proportion of loss up to 100%.

Gages using inductive elements generally flash over at about 1,500 volts, usually at the glass feed-through insulators in the gage case. Paper-base SR-4 strain gages mounted on metal flash over at about 500 volts, through the paper-base, with accompanying destruction of the gage. It was found, however, that the bakelite-based gages, types AB-3 and similar, flash over at 1,500 to 2,500 volts, and then only at the edge where the lead wires protrude, without destroying the gage. If the lead wires are pulled up so that they extend vertically well inside the edge and are surrounded by a spot of insulating cement, they will withstand 5,000 volts, and final failure is at 7,000 to 10,000 volts. This, at first sight, appears to promise satisfactory ruggedness, but such a conclusion ignores the effects of unbalanced currents resulting from flashover at a terminal. The windings of a variable-reluctance transducer will survive a short current pulse of several watt-seconds, while a strain gage winding is destroyed by a short pulse of 0.1 to 0.2 watt-seconds, even though it will dissipate several watts continuously. The damage due to flashover at a terminal or elsewhere can be much greater, therefore, for a strain gage. There is evidence that such a flashover occurs at zero time somewhere in practically every gage circuit on shots like Teapot 12.

To devise further protective means, a synthetic circuit using lumped constants was set up, as shown in Fig. 5.2. In this drawing,



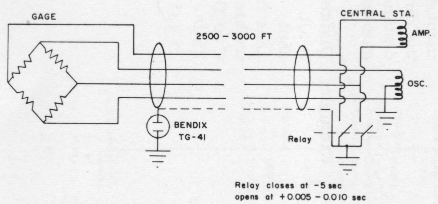
5.2 Synthetic circuit

C_1, C_2, and C_3 are 0.5 mfd, approximately the normal capacitance from shield to ground in a buried cable. R_1, R_2, and R_3, are proportioned to represent the impedance of the earth over a 3,000-foot span. R_4 and R_5 are a 120-ohm half-bridge (the results would be similar with a full bridge and four-wire cable), and R_0 represents the input load of the terminal equipment. C_0 is much larger than C_1, etc., and is charged by E through a resistor. Point F represents the local earth (near the gage). When switch SW is closed, F momentarily jumps to a potential above that of the station earth and decays as C_0 is discharged through R_1, etc. Points A, B, C, and D all rise to the same peak voltage as F but decay faster, since the shield has a lower impedance than the earth. As this voltage decays, then, the potential DF rises to a value smaller than E, but still large. It is important to note that the potentials of A, B, and C follow that of D almost implicity. At no time can any voltage of importance between these points be found, unless they are connected to points D or F separately. The potentials AF, BF, and CF are the ones of interest. When point D is directly connected to point F, AB and C develop no potential to F. This is, however, intolerable for normal field use due to noises from circulating currents.

When a spark gap is placed between D and F, the potential DF (and AF, BF, and CF) is

limited to the breakdown potential of the gap. For input voltages up to 10, 000 volts, an automotive spark plug set for an 800-volt DC breakdown was found to work reasonably well, except that its ionization time was long. This caused the potential to rise to a high peak before breakdown when the voltage rise was fast, endangering the gage before the protection became effective.

Among others, Bendix Aviation Corp., Red Bank Div., offers a series of enclosed spark gaps, among which their type TG-41 has a breakdown voltage of 750 volts, a very fast ionization time, and high current-carrying capacity. These devices were used in the circuit of Fig. 5.3; all strain gage channels of Project 1.7 (Operation Plumbbob) gave usable records and no electromagnetic signal effects were observed.



5.3 Circuit, incorporating Bendix spark gaps

NUCLEAR RADIATION

Undoubtedly the biggest "headache" connected with nuclear radiation measurements is the competition between the various radiative components, e.g., measurements of gamma intensities versus time or versus distance must be made in the presence of fast and slow neutrons and beta particles--so the experimenter must either attempt to protect his instrument from the unwanted radiation or determine the instrument sensitivity to the unwanted component and try to correct his data accordingly. Since the aforementioned difficulty is not peculiar to effects testing (those working with nuclear reactors and radiation damage to materials live with it daily), it will be treated only briefly in this manual. Suffice is to say that neutrons are the most troublesome of the unwanted components--they are difficult to shield against and their effect on calibrated films is energy dependent. However, this does not mean that other radiations are not troublesome. In this section are offered for the project planner rules-of-thumb for estimating radiation severity and therefore its effect on his equipment. A good beginning is Fig. 5.4, a nomograph for calculating exposure from initial radiation and Fig. 5.5 a similar nomograph for calculating exposure to residual radiation. Figure 5.6 is a plot for estimating downwind arrival of fallout. (For fallout calculations, see also Reference 26).

Effects of Radiation on Materials

Radiation intensity is inversely proportional to the square of the distance from the source. Each type of radiation, however, affects materials differently. Slow neutrons are captured by atoms in actuation reactions. This induced artificial radioactivity will generally produce secondary gamma rays, as with cadmium. Boron absorbs slow neutrons and emits alpha particles. Of the two, alpha particles are the more desirable since they are easily stopped. The amount of artificial radioactivity induced by slow neutrons is a function of the cross section for capture possessed by the material. Some metals, notably cadmium, cobalt, and manganese have very large cross-sections for slow neutrons (Table 5.2).

Fast neutrons do not have the large cross section for capture possessed by slow neutrons, but they have a large kinetic energy. Fast neutrons damage by elastic collision with atoms in a crystal structure or chemical compound.

Except for ionization and reactions with electrons, gamma rays are not particularly damaging to electronic equipment until quantities of about 10^{18} gamma rays/cm^2 are reached. Ionization of cable insulation has caused intermittant shorting of gage cables laid both on the surface and in trenches.

5.4. ESTIMATE OF EXPOSURE FROM INITIAL RADIATION

Directions

A. Air and Surface Bursts

1. Find distance from ground zero on axis A (titled Distance-Air and Surface). Note that for sea level bursts, distances are marked off along left side of axis, whereas for bursts at 4500 feet, distances are marked off along right side of axis.

2. Find expected yield on axis B (titled Yield). Again note that for sea level, yields are marked off along left hand side of axis and for 4500 feet, yields are marked off along right hand side of axis.

3. A line drawn between chosen points on A and B will intersect C at a point representing the unshielded dose to be expected.

4. The radiation attenuation provided by various thicknesses of concrete, soil, or lead are found on axis D (titled Attenuation by Shielding).

5. A line drawn between chosen points on axes C and D will intersect axis E at a point representing the shielded dose to be expected.

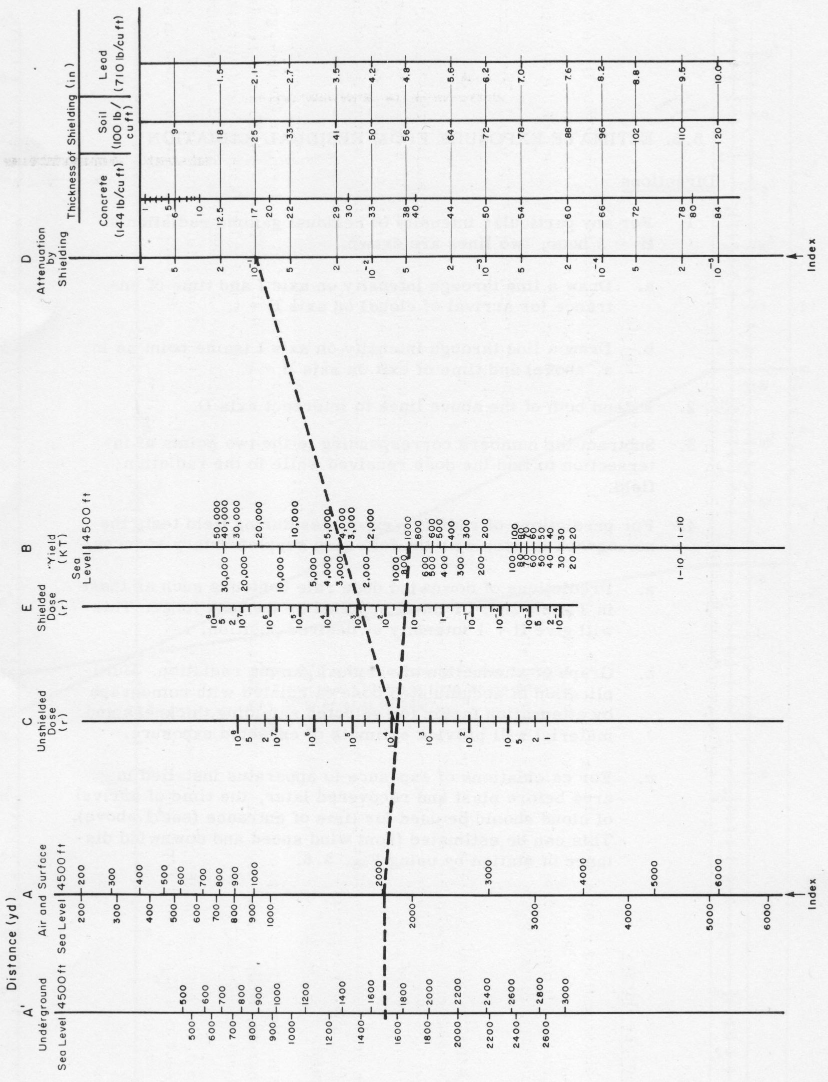
B. Underground Bursts

1. Use Axis A' (titled Distance-Underground). A horizontal line drawn from A' will intersect axis A at a point which can then be used for the remainder of the calculation.

2. Using the intersection on axis A found above, proceed as outlined for Air and Surface Bursts.

Note: It has been assumed that the shelter provided for instrumentation is shielded on all sides and on the top and that the dimensions of the shelter are small compared with distance required for significant attenuation of initial gamma rays in air.

Example: Distance represented 2000 yd from ground zero at 4500 ft alt. (or ~ 1800 yd at sea level; or for underground shot, ~ 1700 yd at 4500 ft and ~ 1550 yd at sea level). Line from axis A to 1000 kt (4500 ft) yield on axis B gives unshielded dose of ~ 8000 r on axis C. Line from Axis C to D (attenuation of 10^{-1}, representing 17 in. concrete, 25 in. soil, 2.1 in. lead gives shielded dose on axis E of ~ 8×10^2 r.



5.4 Estimate of exposure to initial radiation

5.5. ESTIMATE EXPOSURE FROM RESIDUAL RADIATION

<u>Directions</u>

1. For any particular intensity of residual gamma radiation at H + 1 hour, two lines are drawn.

   a. Draw a line through Intensity on axis I and time of entrance (or arrival of cloud) on axis H + t.

   b. Draw a line through Intensity on axis I (same point as in a. above) and time of exit on axis H + t.

2. Extend both of the above lines to intersect axis D.

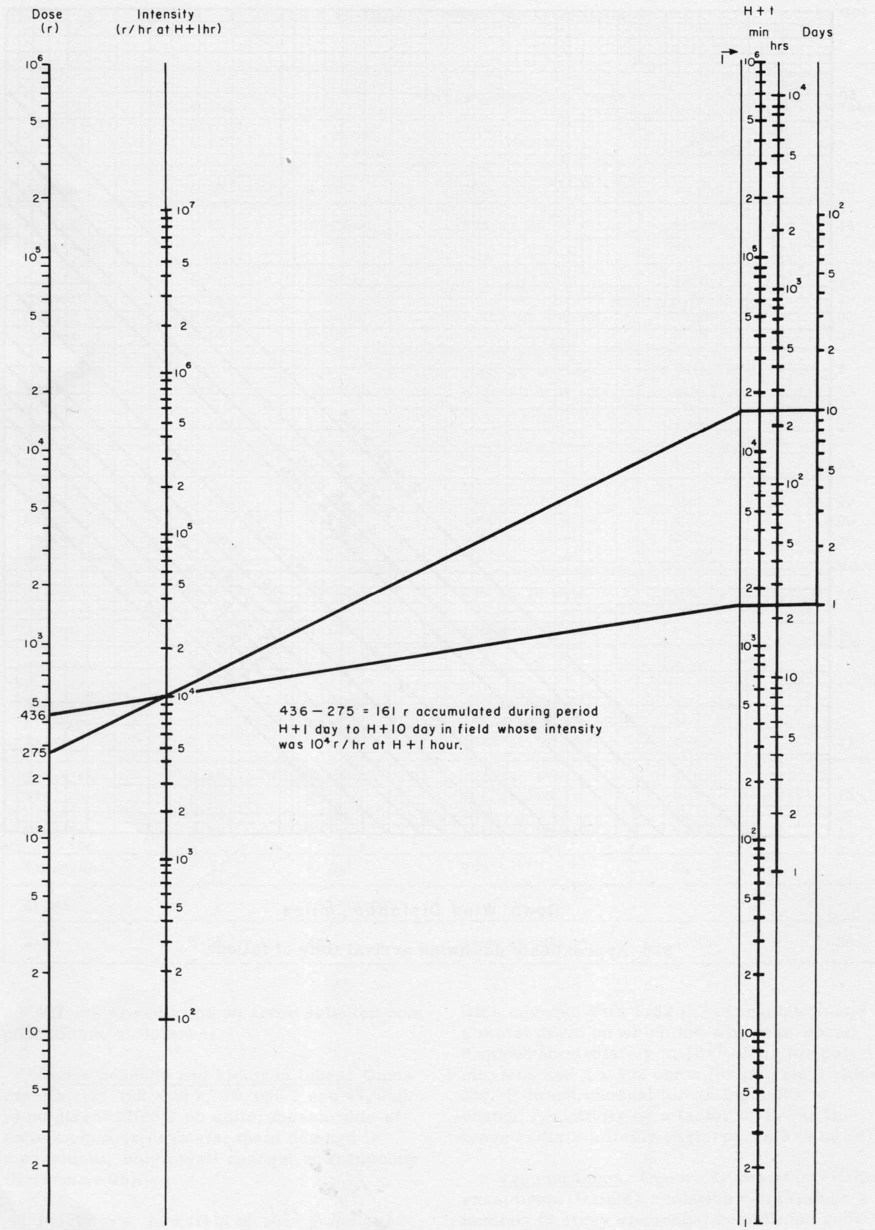
3. Subtract the numbers corresponding to the two points of intersection to find the dose received while in the radiation field.

4. For predictions of radiation exposures during field tests the nomograph is used with the following supplementary sources:

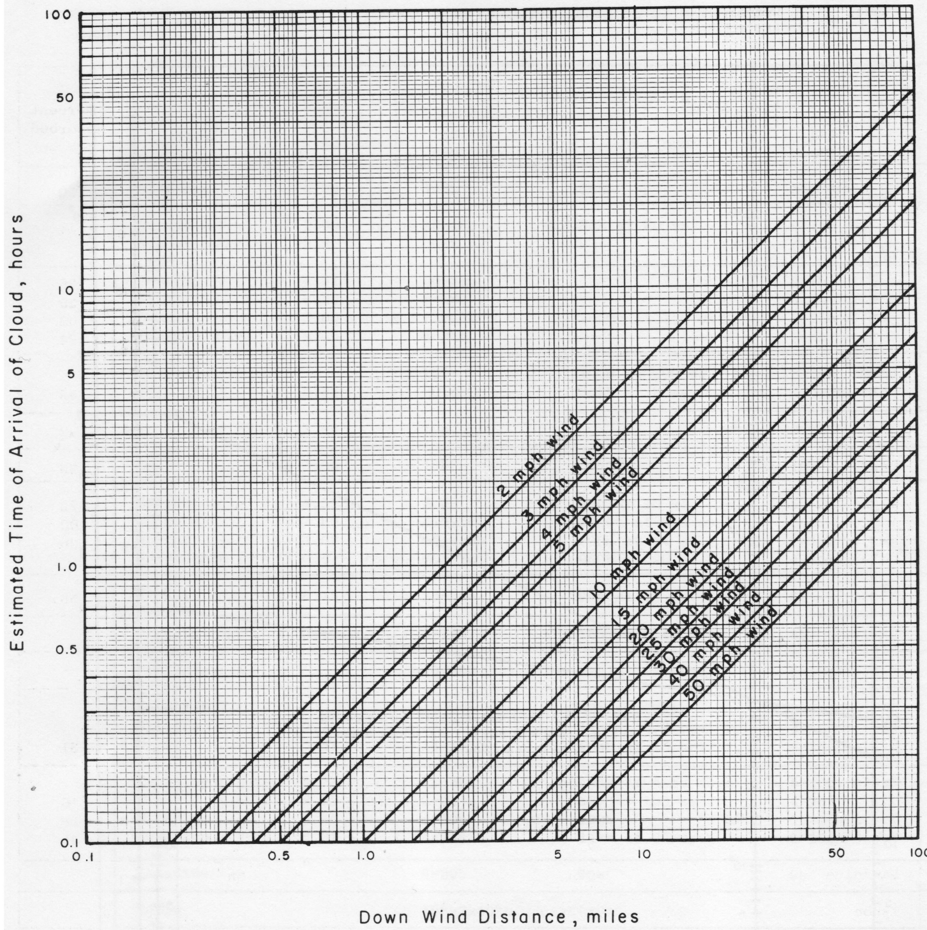
   a. Predictions of downwind dose rate contours such as those in TM 23-200, or those supplied by the task force. This will give H + 1 intensity at desired position.

   b. Graph of attenuation of residual gamma radiation. Multiplication of accumulated dose calculated with nomograph by attenuation factor for selected shielding thickness and material will provide estimate of expected exposure.

   c. For calculations of exposure to apparatus installed in area before blast and recovered later, the time of arrival of cloud should be used for time of entrance (see 1 above). This can be estimated from wind speed and downwind distance of station by using Fig. 5.6.



5.5 Estimate of exposure to residual radiation



5.6 Approximate downwind arrival time of fallout

TABLE 5.2 NUCLEAR PROPERTIES OF MATERIALS

Material	Atoms per cc x 10^{11}	Cross-Section in Barns			Percent absorbed per cm
		Slow neutrons	Maximum	Fast neutrons	
Aluminum	6.03	1.5b	10b	3b	10
Barium	1.53	10-18b	80b at 80 ev	6-12b	14
Beryllium	12.3	6-8 b		6b	
Cadmium	4.61	20-8kb		4-7b	25
Chromium	8.22	6-28b		3.5b	29
Cobalt	9.09	13-40b	7000b at 140 ev	3-20b	100
Copper	8.46	8-35b		2-6b	34
Germanium		10b	100b at 100 ev	3-10b	
Gold	5.89	30-450b	30kb at 5 ev	4.5-10b	43
Iron	8.48	10b		3.7b	42
Lead	3.30	10b		10b	33
Magnesium	4.31	3.5b	22b at 90 kev	5b	22
Manganese	7.89	4.5-20b	2000b at 300 ev	50b	100
Mercury	4.07	45-450b	500b at 34 ev	5-10b	30
Molybdenum	6.4	6.5-15b	900b at 40 ev	4-10b	
Nickel	9.13	25-30b	80b at 16 kev	6b	55
Oxygen	5x10^{19}	4-12b	14b at 0.44 mev	4b	
Platinum		10-20b	2kb at 12 ev	6-10b	
Selenium		10-60b	90b at 27 ev	3.5-10b	
Silicon	5.19	3b	11b at 0.2 mev	3b	
Silver	5.67	18-100b	12kb at 40 kev	4-7b	31
Tantalum	5.53	10-25b	13kb at 4 ev	5-10b	
Tin	2.92	2-5b	60b at 100 ev	4-7b	16
Titanium	5.64	4-10b	100b	5b	28
Tungsten	6.31	8-28b	14kb at 20 ev	5-10b	45
Vanadium		6-20b	70b	6b	
Xenon		10^4-3x10^6b			
Zinc	6.58	4b	140b at 500 ev	3-10b	36

Effects of radiation on some selected components are as follows:

Radar beacons and electron tubes. Gamma effects: (92,000 r, 70,000 r and 47,000 r) no direct effects on units; measurable effects on quartz crystals; main damage is mechanical, only small changes in frequency (Reference 26).

Insulators. In a field of 10^{11} gammas/cm^2-sec, resistance between 5 feet of copper wire covered with 1/32 in. of insulation and a metal drum on which the wire was wound dropped immediately to 10^{11} ohms for polyethylene and 2 x 109 ohms for polyvinyl chloride. It is not unusual for an insulator to change resistivity by a factor of 10^3 in intense radiation fields (References 27 and 28).

Vacuum tubes. Generally resistant--with exceptions. Gamma radiation can produce a number of stray electrons; sometimes radiation will produce a gassy tube. Can be af-

17. Ground Motion Produced by Aboveground Nuclear Explosions: Part I Predictions; Part II Summary and Correlation of Data, SRI Project SU-2206, for AFSWC, Interim Technical Report No. 1, May 15, 1958 (SRD)

18. Water-Wave Measurements, SIO/ONR, Operation Redwing, WT-1308, 1957 (SRD)

19. Measurement of the Magnetic Component of the Electromagnetic Field Near a Nuclear Detonation, DOFL, Operation Plumbbob, ITR-1436, 1957 (SRD)

20. Waveform of Electromagnetic Pulse from a Nuclear Detonation, Operation Hardtack, ITR-1638 (SRD)

21. A Survey of Electromagnetic Effects, Observed during Upshot, UCRL, Operation Upshot-Knothole, WT-797, 1954 (SRD)

22. Supplementary Pressure Measurements, DTMB, Operation Upshot-Knothole, WT-777, 1954 (CRD)

23. Investigation of Early Electromagnetic Signals, LASL, Operation Upshot-Knothole, WT-791, 1954 (SRD)

24. Title classified, NRL, Operation Plumbbob, ITR-1416 (SRD)

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26. Cowan, M., Slide Rule Fallout Calculator, Sandia Corporation Tech Memo 177-57 (51), July 1957 (U)

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28. Coleman, J.H., and Bohn, D., A Method for Increasing the Electrical Resistivity of Insulators to Ionizing Radiation, Jour. of Appl. Phys. 24, 4, (April 1953)

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37. Blast Loading and Response of Underground Concrete-Arch Protective Structures, WES, Operation Plumbbob, ITR-1420, 1957 (C)

38. Capabilities of Atomic Weapons, Department of the Army, TM-23-200, revised edition, July 1955 (SRD)

39. Neutron Flux Measurements, CRL, Operation Redwing, ITR-1313, 1956 (SRD)

40. Characterization of Fallout, NRDL, Operation Redwing, ITR-1317, 1956 (SRD)

41. Nuclear Radiation Handbook

42. Ground Acceleration, Stress, and Strain at High Incident Overpressures, SRI, Operation Plumbbob, ITR-1404, 1957 (CTRD)

43. Benderly, A.A., Shock Proof Packaging of Subminiature Vacuum Tubes, Shock and Vibration Bulletin, No. 24, February 1957, Office of Secretary of Defense, Research and Development (U)

44. Robbins, J.D., Recording Transients of Electron Tubes under High Impact Shock, Shock and Vibration Bulletin, No. 24, February 1957, Office of Secretary of Defense, Research and Development (C)

TABLE 6.2 CROSS-SECTIONS FOR TOWER HEIGHTS

Tower height (ft)	Peak drag pressure $\bar{=} p_{do}$ (lb/in.^{2})	Positive-phase duration (msec)	Drag coefficient $= C_d$	For Recommended Section: Fixed-end dynamic moment $= M_D$ in.lb.x10^3	Recommended Two-Pipe Section: Pipe O.D. (in.)	Pipe Wall thick. (in.)	O. C. spacing (in.)	Width of 1" plate (in.)
3	80	380-470	1.50	1,622	8-5/8	.322	16	12
5	350	300	1.50	17,000	8.0	1.500	24	20
5	80	380-470	1.50	4,128	8-5/8	.500	16	12
5	20	600	1.50	1,045	8-5/8	.322	16	12
10	150	300	1.50	30,210	9.0	2.000	27	23
10	80	380-470	1.50	14,465	8.0	1.250	24	20
10	20	600	1.50	4,862	8-5/8	.500	16	12
40	10	700	1.05	15,435	8.0	1.500	24	20

The general conclusions concerning calculations of maximum dynamic bending moment at the base of the towers are as follows:

1. The practice of taking the maximum dynamic moment equal to double the maximum static moment is always on the conservative side. However, where t_d/T is less than about 3, this approximation is too conservative and the exact ratio of the maximum M_D/M_S should therefore be used.

2. Effects of damping were neglected. Had damping been considered, the amplitude of the variations in the dynamic moment would have decreased with time and the dynamic moment would probably approach coincidence with the static moment as $t + t_d$.

M_D = dynamic bending moment at fixed-end of tower

M_S = maximum static-fixed end moment

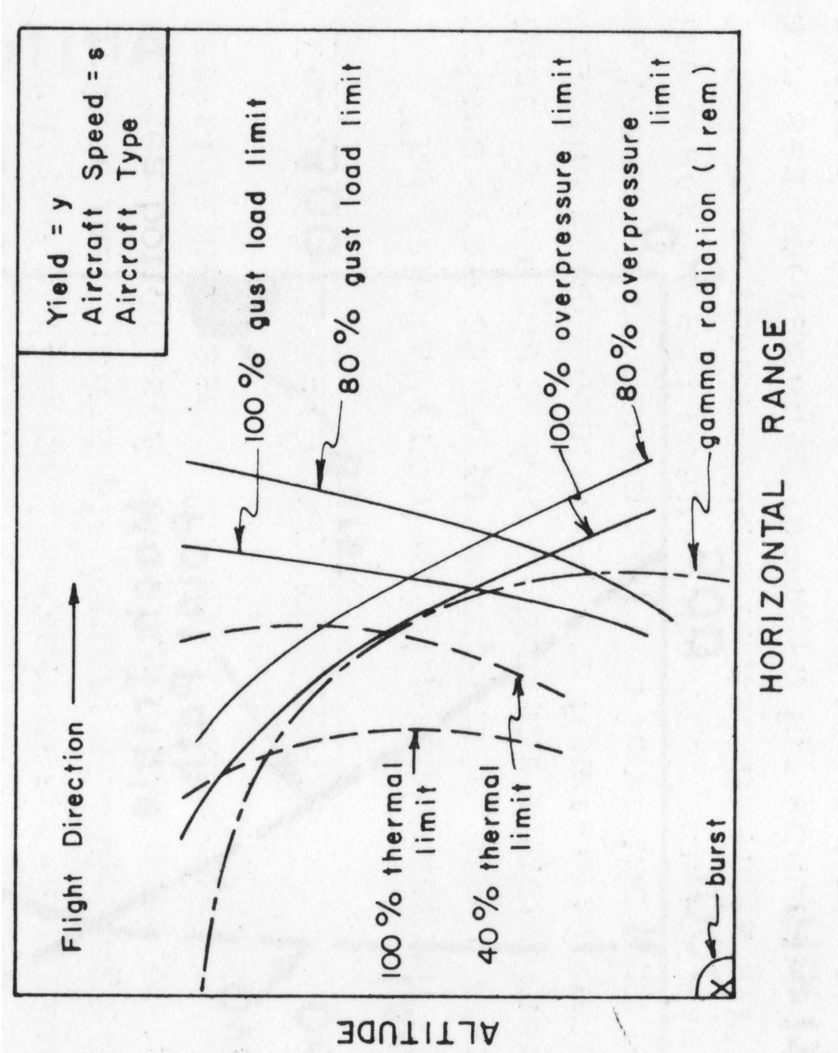
t = time

T_1 = fundamental natural period of vibration of tower (T)

t_d = effective duration of drag pressure (taken as $t_o/2$)

t_o = duration of positive phase of blast wave

3. For the size instrument mounts considered in this design their contribution to the total dynamic moment could be neglected without serious error. "A" frame steel configuration has been used successfully as mounting towers for instrumentation (NRDL)(Fig. 6.8).



8.3 Danger region diagram

Project officers are required to keep a running record of the cumulative exposure of their personnel to facilitate Rad-Safe control.

Rad-Safe does not register film badge readings less than 35 milliroentgens (mr). A considerable dose can thereby be built up by successive reentry if film badges are turned in after every reentry. This fact should be borne in mind, and personnel should note carefully their dosimeter readings and the radiation rate so that a film badge is turned in when it registers 35 mr or over.

In general, the time when fallout and residual radiation is most intense on the blast line is up to H + 2 hr; thus if the experiment plan is not seriously affected by entry after H + 2 hr, personnel burnout problems can be alleviated by the later entry.

RAD-SAFE

On-site radiation safety services include the following:

1. Continuing surveys and briefings of the radiological situation at the site.

2. Monitor training and monitoring assistance (if requested).

3. Issuance of film badges and monitoring equipment and maintenance of personnel dosimetry records.

4. Maintenance and issuance of protective clothing and equipment.

5. Decontamination facilities for personnel, vehicles, clothing, and equipment.

6. Registry of radioactive sources used or stored at site, and advice on preparation of radioactive materials for shipment from site.

In Nevada, the DOD Test Group has a Rad-Safe coordinator who acts as liaison officer with the Rad-Safe advisor to the test director and on-site Rad-Safe Group (REECO). In the Pacific, TG 7.1 maintains its own Rad-Safe function.

RECOVERY PROCEDURE

Several days before the shot in which a project is scheduled to participate, the program director calls for "event cards" from each project. On these cards are listed the project's button-up and recovery party, area of operation, time of entry and departure on D-1, or D-2 if EPG, time of reentry and departure postshot. From these event cards, an operations plan is made for the test group director and the test director's organization.

10.1 Postshot damage survey team, EPG

Rad-Safe Surveys

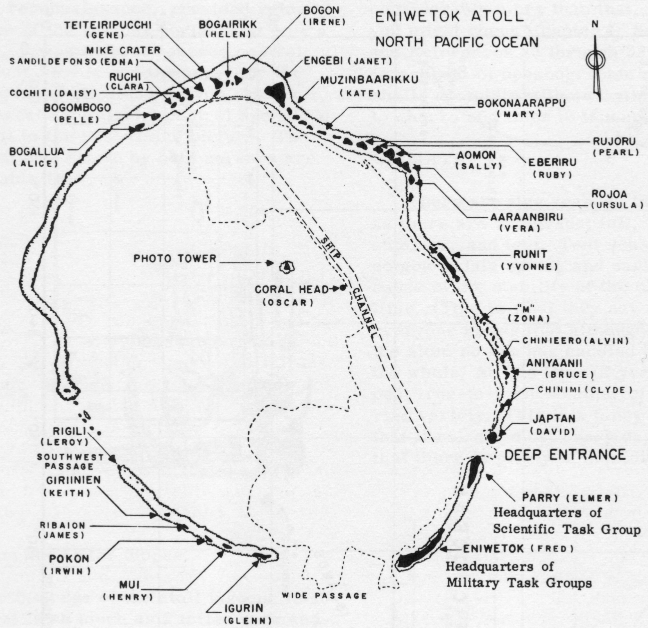
Rad-Safe surveys are begun at about H + 15 minutes, and the results of these surveys are posted in designated places at the site to indicate the intensity and extent of radiation. They are kept up-to-date for the remainder of the operation. When the radiation reaches a safe level, R-hour, or reentry time, for those not requiring early entry, is proclaimed. Areas are designated as follows:

Radex: radiological exclusion area.

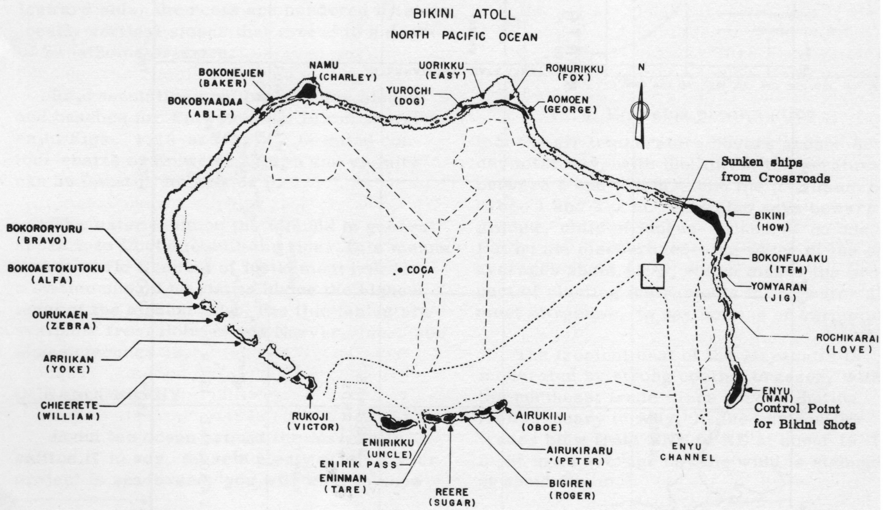
Full Radex: an area in which the radiation contamination exceeds 100 mr/hr gamma.

Limited Radex: an area in which radiation intensity is between 10 and 100 mr/hr gamma.

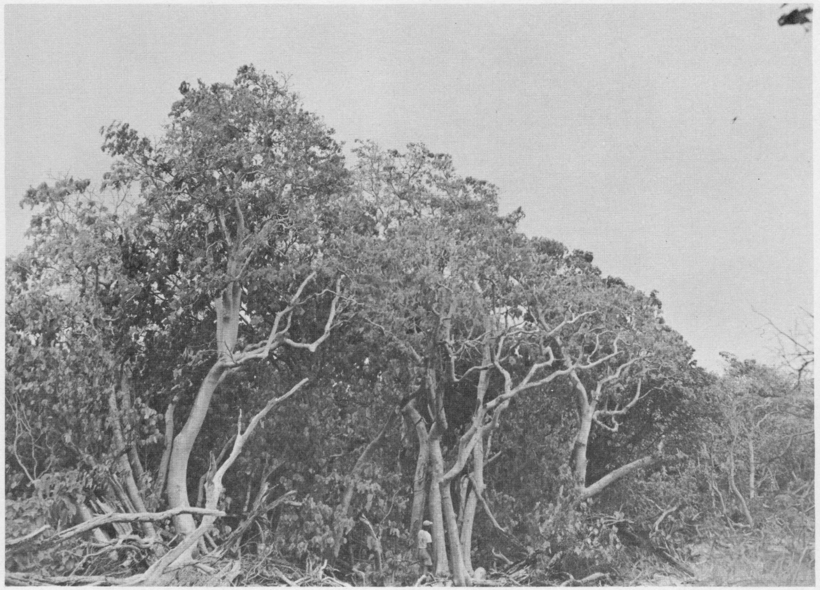
Recovery parties are seldom allowed in high intensity fields (greater than 10 r/hr).



13.1 Eniwetok Atoll



13.2 Bikini Atoll



13.7 Typical EPG terrain (Bikini), pisonia grove (top), palm grove (bottom)

13.11 Typical EPG terrain (Bikini), preshot

13.12 Typical EPG terrain (Bikini), postshot

TABLE 13A.1 MEAN WINDS ALOFT, ENIWETOK ATOLL, 1953 THROUGH 1957

Level (ft)	Direction (°)	Force (knots)	Std Vector Deviation* (knots)	No. Obs.	σ_x/σ_y	Level (ft)	Direction (°)	Force (knots)	Std Vector Deviation* (knots)	No. Obs.	σ_x/σ_y
		APRIL						MAY			
9,843	090	9.3	10.6	457	1.41	9,843	095	9.8	9.2	462	1.32
19,685	074	5.5	13.9	458	1.52	19,685	092	1.9	11.7	459	1.46
29,528	272	8.3	22.7	457	1.77	29,528	266	12.1	16.7	454	1.49
39,370	260	21.4	25.9	453	1.39	39,370	260	25.9	23.4	442	1.40
49,212	281	18.6	23.3	421	1.61	49,212	274	25.3	22.7	423	1.32
59,156	030	5.0	15.5	340	1.59	59,156	046	3.0	13.1	366	1.36
68,897	086	9.1	14.6	301	2.22	68,897	093	15.6	14.5	318	2.14
78,739	092	18.0	23.0	274	2.37	78,739	092	26.7	21.8	275	2.88
88,582	091	25.3	28.6	215	3.01	88,582	091	34.4	26.4	223	2.80
98,424	092	30.9	30.8	123	2.32	98,424	093	39.1	28.0	123	3.12
		JUNE						JULY			
9,843	097	12.8	9.0	397	1.44	9,843	096	12.6	8.5	418	1.34
19,685	089	9.0	10.8	393	1.60	19,685	093	8.5	9.9	410	1.02
29,528	325	0.5	15.4	381	1.44	29,528	283	0.7	14.0	400	1.16
39,370	256	12.5	19.5	373	1.20	39,370	267	8.0	21.5	394	1.12
49,212	273	15.1	18.8	344	1.35	49,212	259	11.4	19.8	368	1.10
59,156	085	13.1	12.2	263	1.69	59,156	093	19.1	12.0	306	1.55
68,897	092	25.7	14.6	235	1.81	68,897	091	29.8	15.8	276	2.33
78,739	092	35.7	23.2	211	3.85	78,739	091	39.6	22.1	245	2.58
88,582	093	45.5	24.9	158	3.13	88,582	092	49.4	23.8	198	2.51
98,424	091	43.0	28.6	78	2.26	98,424	093	53.6	23.8	96	1.67

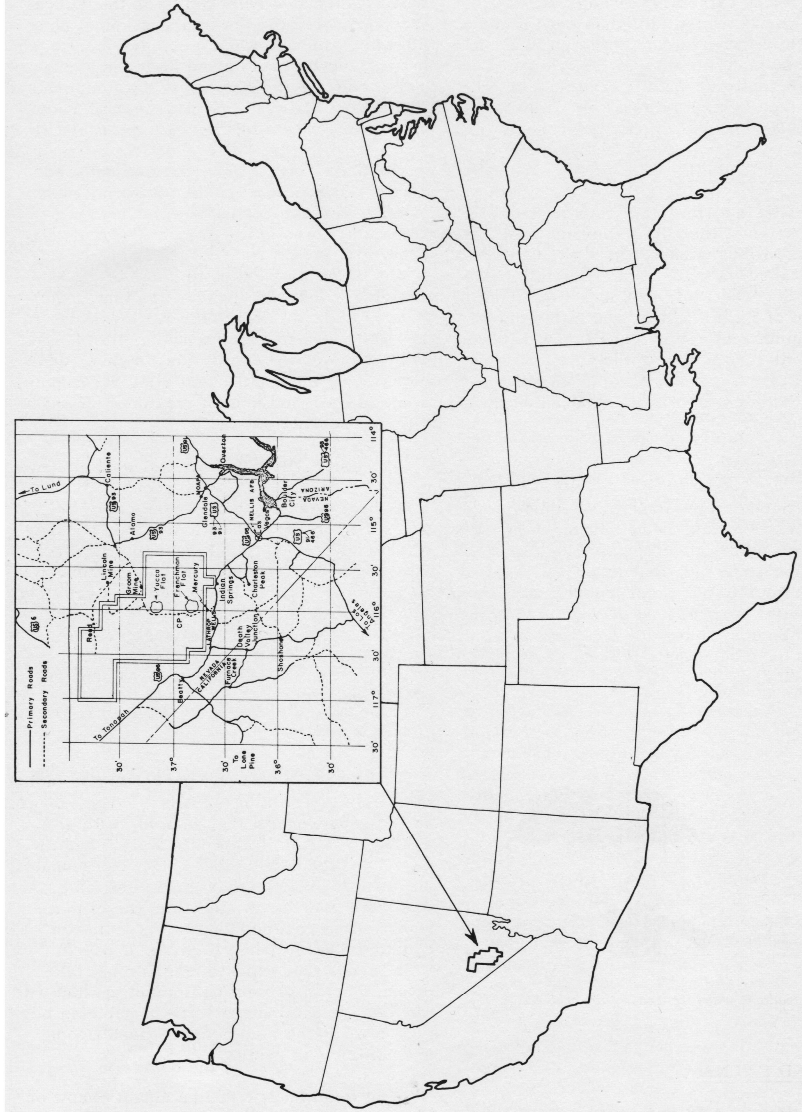
* Computed for an equivalent circular distribution of vector variability.

σ_x/σ_y = ratio of std. devia. of east-west to std. devia. of north-south wind components; if the distribution is circular $\sigma_x/\sigma_y = 1$.

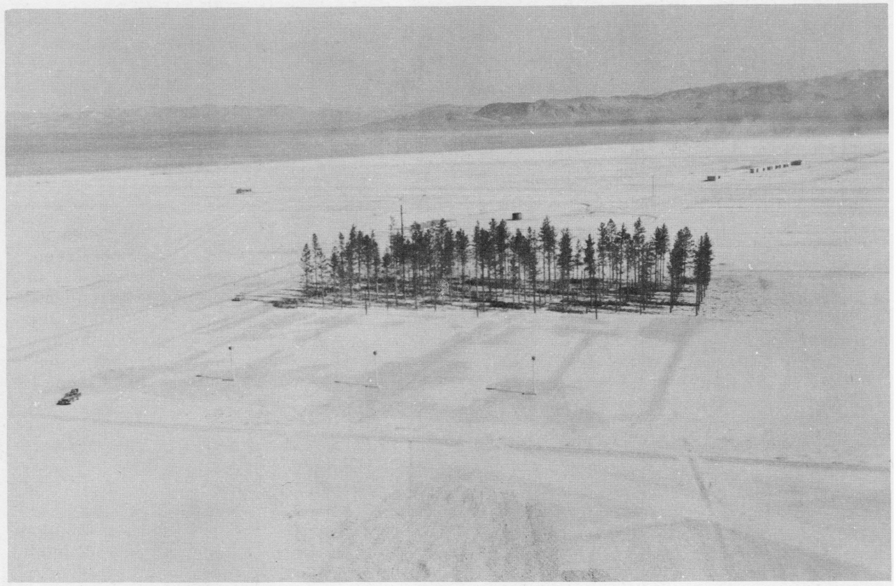
TABLE 17.1 POPULATION BREAKDOWN BY ATOLL*

Ailinglaplap	1,304
Ailuk	390
Arno	978
Aur	472
Ebon	745
Jaluit	1,154
Kwajalein (incl. Ebeye)	1,278
Kili Island	201
Lae	104
Likiep	596
Lip Island	63
Majuro	2,294
Maloelap	510
Mejit Island	245
Mille	361
Namrik	533
Namu	420
Ronglap	174
Ujae	180
Utrik	186
Wotho	47
Wotje	380
Ujelang	193
Approximate total	12,808

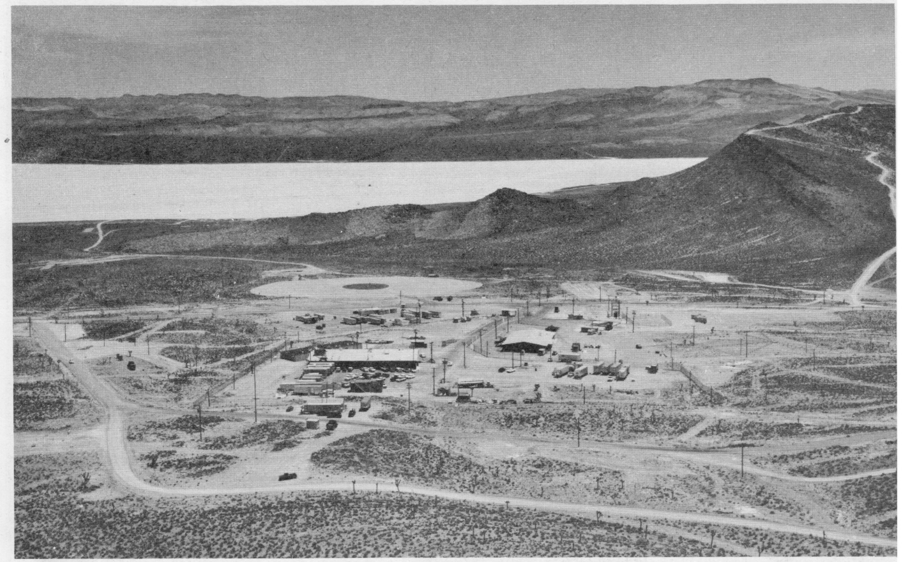
* Compiled April 1956



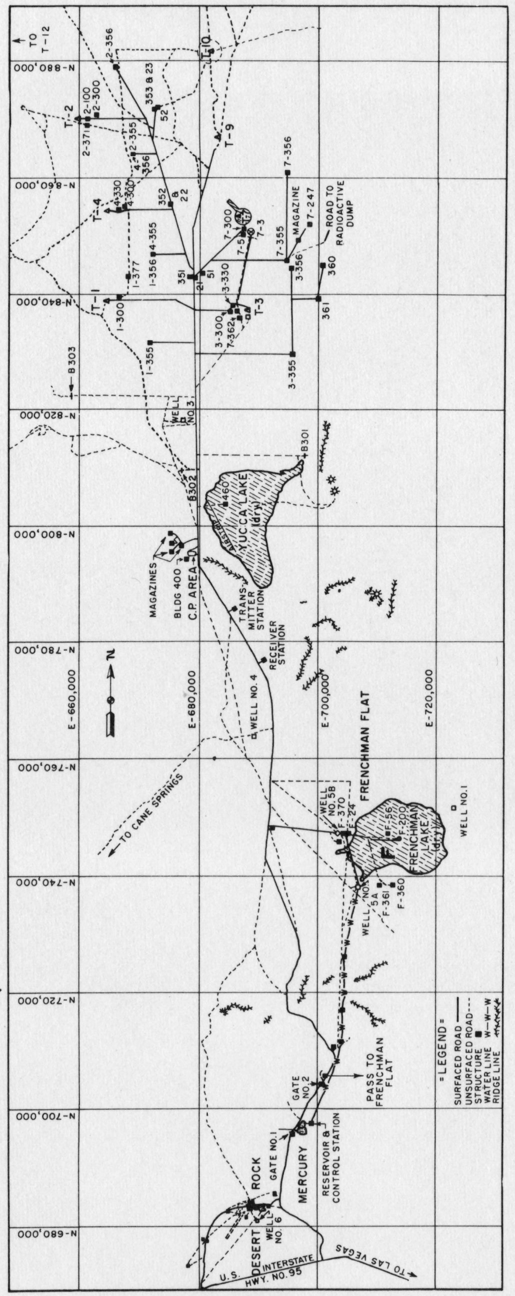
18.1 Location of Nevada Test Site



18.2 Typical terrain, Frenchman Flat (tree stand is atypical)



18.3 Typical terrain, Yucca Flat (overlooking Control Point, heliomat, and playa of dry lake--Joshua trees foreground are typical)



18.7 Layout, NTS

Supplement 18A
STANDARD TREATMENT OF SNAKE BITES AND SCORPION STINGS

SNAKE BITES

Immediate Treatment

Tourniquet. Apply the tourniquet lightly, just denting the skin, about six inches above the bite or area of swelling, if the bite is on an extremity.

Incisions. Incision or cutting of the fang marks is not advisable for by the time this can be done the venom has spread upwards and around the bite. The incisions or cuts should be about 1/8-inch deep and about 1/2-inch apart, just ahead of the swelling. Suctions should then be applied to the cuts and this should be repeated time and again. As the swelling advances another circle of incisions should be made about 3-inches from the preceding ring of cuts. Then repeated suction should be applied to this new ring of cuts. If the swelling continues to advance, similar rings of incisions should be made and repeated suction done. ADVANCE THE LIGHTLY PLACED TOURNIQUET AHEAD OF THE SWELLING AND INCISIONS. As the swelling advances the tourniquet is advanced and the incisions are made between the tourniquet and the line of swelling.

Warning

The individual bitten must not get excited and run. He should get away from the snake and then sit down and immediately apply a tourniquet, which in an emergency may be a tie, belt, or handerkerchief. Then either wait for help, or if in an isolated area, proceed as quietly and with as little effort as possible to your nearest transportation and nearest Aid Station. If you do not have a snake bite kit available, emergency treatment will be given at the Aid Station and immediate transportation provided to the NTS Dispensary at Mercury. If you have a snake bite kit, carry out the above instructions by applying the light tourniquet and then the first ring of incisions. After this proceed to your nearest Aid Station.

SCORPION STING

A scorpion sting is accompanied by a sharp, burning pain and an area of numbness around the puncture. In cases of a severe reaction, the victim may develop slurred speech and difficulty in breathing. He may become drowsy. Pain may be excruciating. Proceed to the nearest Aid Station for the following treatment.

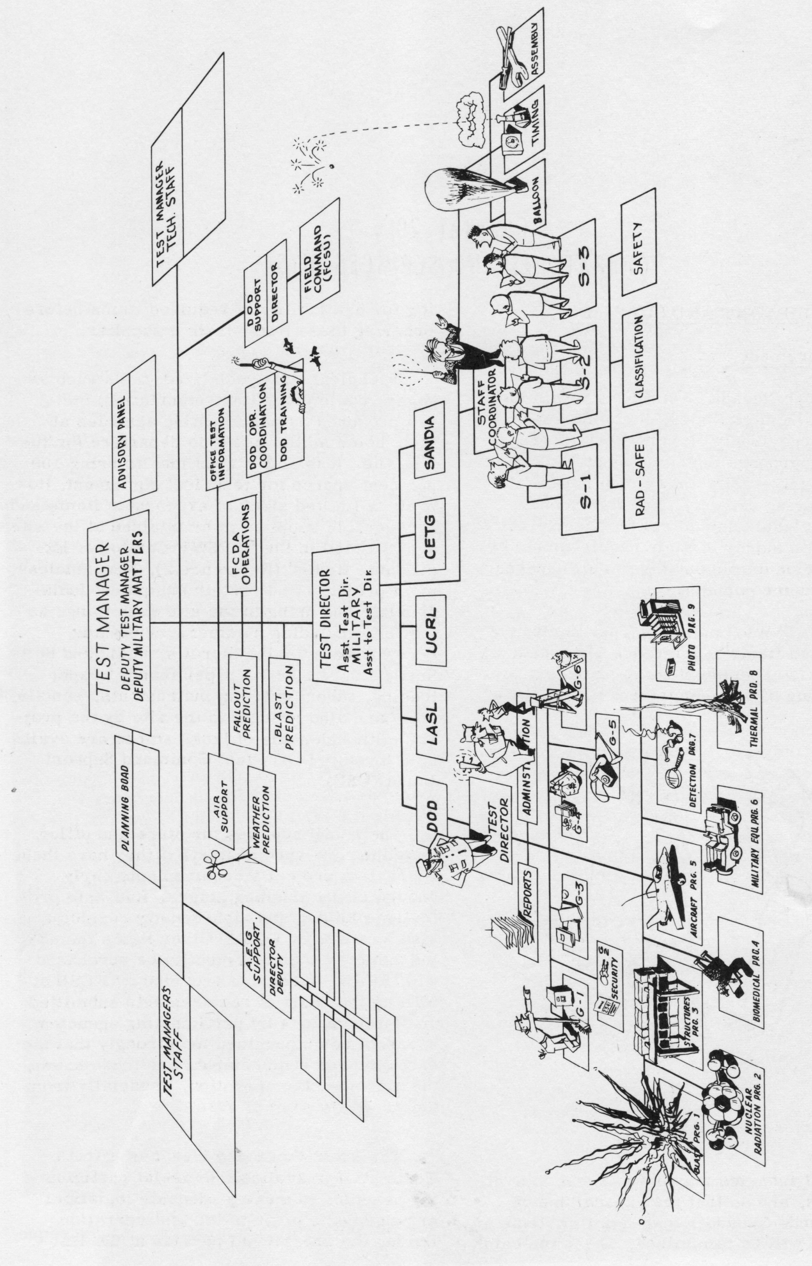
Treatment

As soon as possible apply ice wrapped in a cloth, or an ice bag, to the sting. Morphine sulfate 1/4 to 1/2 grain given intramuscularly. DO NOT GIVE DEMEROL. Local pain may be controlled by the local injection of Procaine or Novocaine. Convulsions may be controlled by the injection of Luminal Sodium or Pentathol Sodium. Antivenin, if available, may be used.

TABLE 18.3

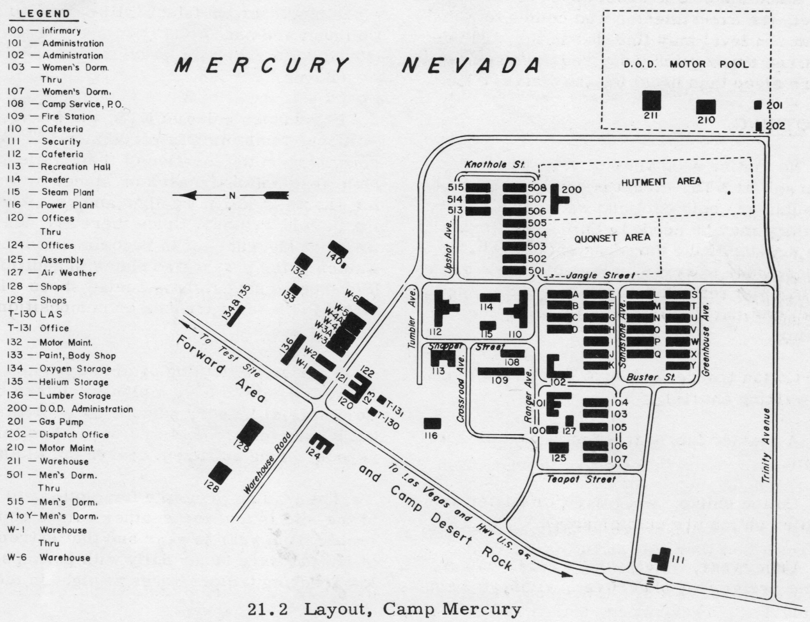
PERCENTAGE FREQUENCY OF WINDS BY DIRECTION AND SPEED
(From Five Years of Las Vegas Soundings)
500 Millibars (18,000 Feet, MSL)
0700 PST

	Speed (mph)	Direction																All Directions
		N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	
Jan-Feb	1-19	1.0	1.0	0.3	0.3	0	0	0.7	0	0.7	0.3	0.3	1.0	0.7	2.0	1.3	0.3	10.0
	20-29	4.3	1.0	0	0	0	0	0.3	1.0	1.0	1.3	3.0	4.7	7.0	4.0	4.7	3.0	35.3
	40-59	1.0	1.3	0.7	0	0	0	0.3	0	0	1.3	2.7	5.7	6.0	5.7	3.3	2.3	30.3
	60-99	1.3	1.0	0	0.7	0	0	0	0	0.3	0	4.3	4.0	2.3	3.3	2.0	2.3	21.7
	>100	0	0	0	0	0	0	0	0.3	0	0.7	0.7	0.3	0	0	0.3	0.3	2.7
	All Speeds	7.7	4.3	1.0	1.0	0	0	1.3	1.3	2.0	3.7	11.0	15.7	16.0	15.0	11.7	8.3	100.0
Mar-Apr	1-19	1.0	1.6	1.0	0	0	0.7	0.3	0.7	0.3	1.3	0.3	1.6	1.6	2.3	1.6	1.3	15.6
	20-39	2.6	1.0	1.3	0.3	0	0.7	1.0	0	0.7	1.9	3.2	5.7	6.8	6.5	4.2	3.3	39.3
	40-59	1.6	0.3	0	0	0	0	0	0.3	0.7	2.3	3.9	4.2	5.8	2.9	3.6	1.6	27.3
	60-99	1.9	0	0	0	0	0.3	0	0	0.7	1.0	2.3	3.2	2.3	1.9	2.3	1.9	17.5
	>100	0	0	0	0	0	0	0	0	0	0	0	0	0.3	0	0	0	0.3
	All Speeds	7.1	2.9	2.3	0.3	0	1.6	1.3	1.0	2.3	6.5	9.7	14.6	16.9	13.6	11.7	8.1	100.0
May-June	1-19	0	2.6	2.0	0	0.7	0.7	1.3	0.7	1.6	3.0	2.6	1.0	3.6	2.3	2.3	3.6	28.1
	20-39	0.3	0.7	0.7	0	0	0.3	0.3	0	1.6	2.3	8.6	7.0	7.0	3.6	3.0	4.0	39.5
	40-59	1.3	0	0	0	0	0	0.3	0	1.0	5.6	6.6	3.3	3.3	3.0	1.0	0.3	25.8
	60-99	0	0	0	0	0	0	0	0.3	0.7	1.3	1.0	1.3	0.3	0.3	1.0	0	6.3
	>100	0	0	0	0	0	0	0	0	0	0	0	0	0.3	0	0	0	0.3
	All Speeds	1.6	3.3	2.7	0	0.7	1.0	2.0	1.0	5.0	12.2	18.9	12.6	14.5	9.2	7.3	7.9	100.0
July-Aug	1-19	0.3	0.7	1.9	1.9	1.6	1.6	3.3	5.5	4.5	6.3	8.4	7.7	3.9	2.9	0.7	1.0	52.1
	20-39	0	0.3	0	0	0	0	1.9	1.9	4.2	8.0	12.5	7.7	1.9	1.9	0.7	0	41.2
	40-59	0	0	0	0	0.3	0	0	0	0.3	1.9	1.0	2.9	0	0	0	0	6.4
	60-99	0	0	0	0	0	0	0	0	0	0	0	0	0	0.3	0	0	0.3
	>100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	All Speeds	0.3	1.0	1.9	1.9	1.9	1.6	5.2	7.4	9.0	16.2	21.9	18.3	5.8	5.2	1.3	1.0	100.0
Sept-Oct	1-19	1.6	1.3	1.0	1.3	1.0	1.7	2.3	1.7	4.0	2.7	4.0	3.0	3.6	3.3	2.0	1.7	36.1
	20-39	1.3	1.3	0.7	0.7	0.7	0.7	1.0	0.7	1.3	7.3	6.0	6.0	6.3	4.0	4.3	2.3	44.5
	40-59	0.7	0.3	0	0	0.3	0	0	0	0.7	1.7	3.6	4.3	2.0	1.3	0	0	14.9
	60-99	0	0	0	0	0	0	0	0	0	1.0	1.0	0.7	0	1.0	1.0	0	4.6
	>100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	All Speeds	3.6	3.0	1.7	2.0	2.0	2.3	3.3	2.3	6.0	12.6	14.6	13.9	11.9	9.6	7.3	4.0	100.0
Nov-Dec	1-19	0.3	0.3	1.3	0.3	1.3	0.3	0.3	1.0	0.7	1.6	1.0	2.0	3.0	2.0	1.6	2.0	19.1
	20-39	2.0	1.6	0	0.3	0.7	0	1.0	0.7	1.6	1.3	2.3	3.6	7.9	4.9	4.0	3.6	35.5
	40-59	1.3	1.0	0	0	0	0	0	0.3	0.3	1.0	3.6	1.3	4.6	4.9	3.6	3.0	25.0
	60-99	1.6	0	0	0	0	0	0	0.3	0	0.3	2.3	3.6	3.3	3.3	2.0	3.0	19.7
	>100	0	0	0	0	0	0	0	0	0	0	0	0.3	0	0	0.3	0	0.7
	All Speeds	5.3	3.0	1.3	0.7	2.0	0.3	1.3	2.3	2.6	4.3	9.2	10.8	18.8	15.1	11.5	11.5	100.0
200 Millibars (40,000 Feet, MSL)																		
Jan-Feb	1-19	0	0	0	0	0	0	0	0	0	0	0	0	0.4	0	0	0	0.7
	20-39	0.4	0	0	0.4	0	0	0.4	0	0.4	0.4	1.1	0.4	3.3	0.7	1.8	0.7	9.8
	40-59	0.4	0.4	0	0.4	0	0	0	0	0	0.4	2.5	1.4	7.6	7.6	4.3	2.2	27.0
	60-99	1.8	0.4	0.4	0	0	0	0	0	0	1.1	4.0	10.5	11.6	8.0	5.4	1.8	44.8
	>100	0.4	0	0	0	0	0	0	0	0.4	0.4	1.8	5.0	5.0	2.9	0.4	1.4	17.7
	All Speeds	2.9	0.7	0.4	0.7	0	0	0.4	0	0.7	2.2	9.4	17.3	27.8	19.2	12.3	6.1	100.0
Mar-Apr	1-19	0.3	0.3	0	0	0.3	0	0	0	0	0	0.3	0.3	0	0.3	0	0.3	2.3
	20-39	0.3	1.0	1.0	0	0	0	0	0	0.3	0.3	1.3	2.3	3.4	0.7	3.0	1.7	15.5
	40-59	1.7	0.3	0	0	0	0	0	0	0	0.7	2.0	4.0	6.4	4.7	3.0	1.3	24.1
	60-99	1.0	0	0	0	0	0	0	0	0	0.7	4.4	9.4	12.8	4.0	2.3	4.0	38.6
	>100	0.3	0	0	0	0	0	0	0	0	0	1.3	7.0	4.0	3.4	2.3	1.0	19.5
	All Speeds	3.7	1.7	1.0	0	0.3	0	0	0	0.3	1.7	9.4	23.1	26.6	13.1	10.7	8.4	100.0
May-June	1-19	0	0.3	0.3	0.3	0.3	0.7	0	0	0.3		0.3	1.0	0.7	0.7	1.3	0	7.0
	20-39	1.7	0.3	0	0	0	0	0	0.3	1.3	0.3	0.7	2.0	3.7	2.0	1.3	1.0	14.7
	40-59	0.3	0.3	0	0.3	0	0	0	0	1.3	1.7	2.0	5.0	7.4	4.0	2.0	1.3	25.8
	60-99	0.7	0.3	0.3	0	0	0	0	0	0.3	2.7	10.4	10.0	9.0	4.3	2.0	0.3	40.5
	>100	0	0	0	0	0	0	0	0	0.7	0.3	4.7	2.7	1.7	1.3	0.3	0.3	12.0
	All Speeds	2.7	1.3	1.0	0.7	0.3	0.3	0.7	0.3	3.7	5.4	18.1	20.8	22.4	12.4	7.0	3.0	100.0
July-Aug	1-19	0	0.3	0.3	0	0	0	0	1.0	0	0.3	0.3	1.6	0.3	1.3	0.3	1.3	7.2
	20-39	0	0	1.0	0	0.7	0.3	0.3	2.3	3.3	2.6	8.6	6.9	4.3	3.3	0	0.3	33.9
	40-59	0	0	0	0	0	0	0.3	0.7	1.6	4.6	11.8	10.2	6.9	1.6	0.3	0	38.1
	60-99	0.3	0	0	0	0	0	0	0	0.3	2.6	8.2	5.9	1.6	1.0	0	0	20.1
	>100	0	0	0	0	0	0	0	0	0	0	0.3	0.3	0	0	0	0	0.7
	All Speeds	0.3	0.3	1.3	0	0.7	0.3	0.7	0.4	5.3	10.2	29.3	24.9	13.2	7.2	0.7	1.6	100.0
Sept-Oct	1-19	0.7	0	0	0	0.7	0	0.3	0	0.7	0.3	0.3	2.4	0	0.3	0.7	0	6.4
	20-39	0.7	0.3	0.3	1.0	0.3	0	0	0.3	0.7	1.0	4.4	3.7	5.4	5.1	3.4	1.7	28.5
	40-59	0.7	0	0	0	0	0	0	0.3	0	0	3.4	6.4	4.7	5 1	3.4	1.4	25.4
	60-99	0.7	0	0	0	0	0	0	0	0	0.3	6.4	9.8	9.5	4.4	1.4	0.3	32.9
	>100	0	0	0	0	0	0	0	0	0	0.3	1.7	3.7	0.7	0.3	0	0	6.8
	All Speeds	2.7	0.3	0.3	1.0	1.0	0	0.3	0.7	1.4	2.0	16.3	26.1	20.3	15.2	8.9	3.4	100.0
Nov-Dec	1-19	0.7	0	0	0	0	0	0.7	0.7	0	0.7	0.3	1.0	0.7	0.3	1.0	0.3	6.3
	20-39	0.7	0	0	0	1.0	0	0.7	0.7	0.3	1.0	2.0	1.3	2.0	1.0	3.0	1.7	15.2
	40-59	0.3	0	0	1.0	0	0	0	0.3	0.3	0	0.7	2.7	6.0	5.0	4.3	1.7	22.2
	60-99	0.3	0.7	0	0	0	0	0	0	0	0	4.0	6.6	12.3	7.3	5.0	2.3	38.4
	>100	0	0.3	0	0	0	0	0	0	0	0	0.7	7.0	2.7	4.3	3.0	0	17.9
	All Speeds	2.0	1.0	0	1.0	1.0	0	1.3	1.7	0.7	1.7	7.6	18.5	23.5	17.9	16.2	6.0	100.0

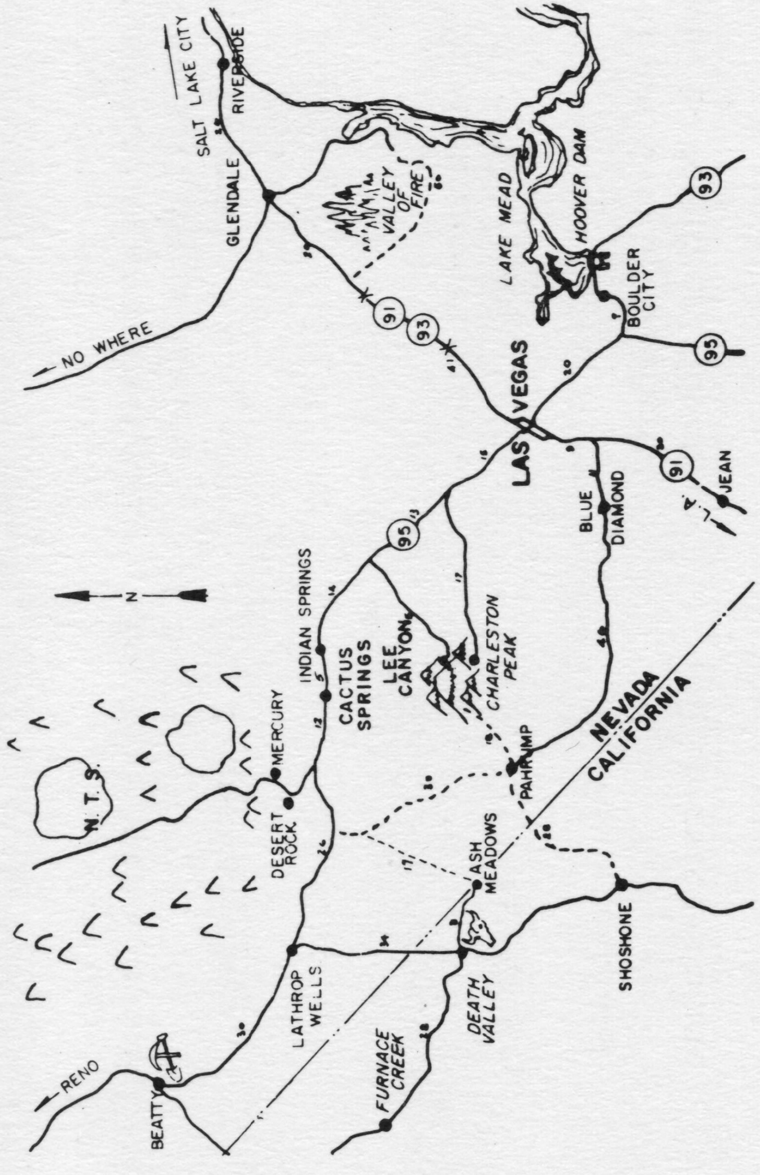


19.1 Nevada Test Organization

21.1 Aerial view, Camp Mercury (circa AD 1952)



21.2 Layout, Camp Mercury



21.3 Hither and thither from Mercury

PRINCIPLES OF
RADIATION AND CONTAMINATION CONTROL

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BUREAU OF SHIPS NAVY DEPARTMENT WASHINGTON 25, D. C.

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U. S. NAVAL RADIOLOGICAL DEFENSE LABORATORY

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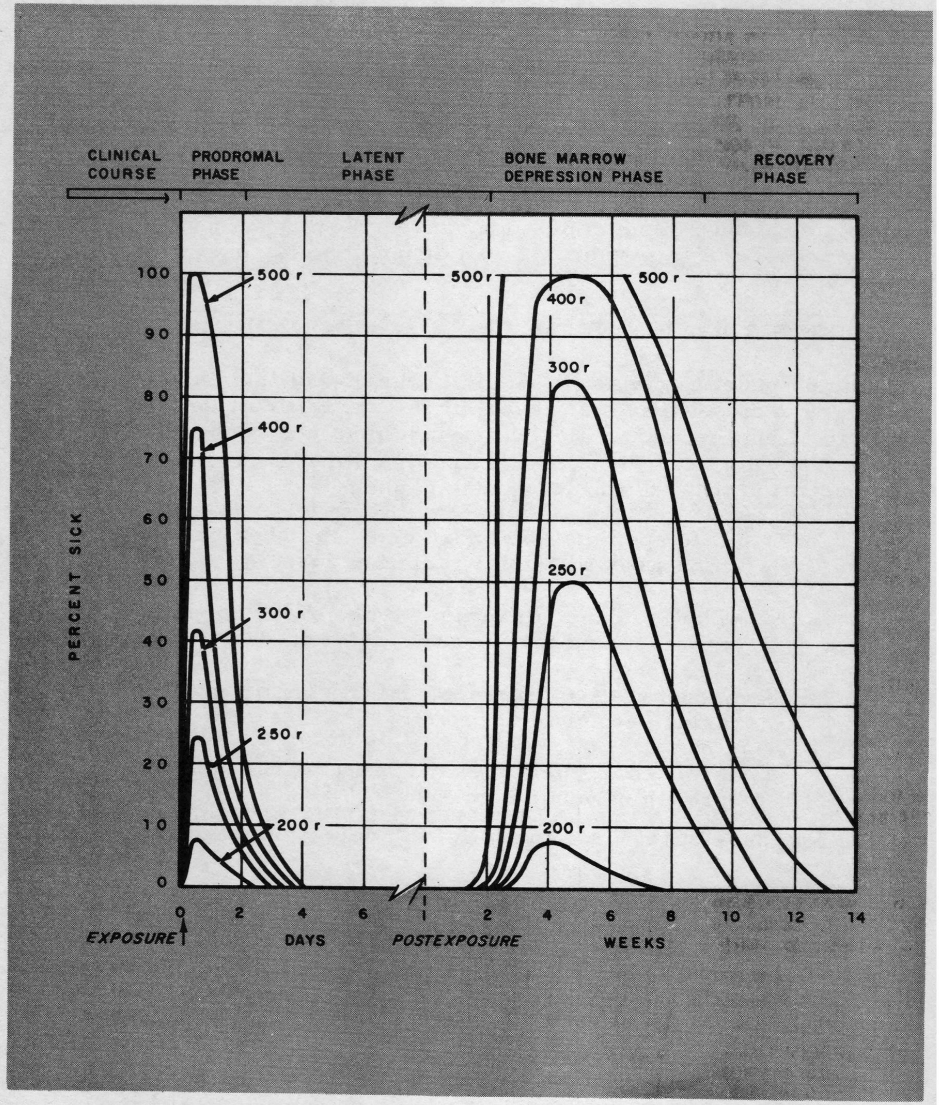


FIG. 1.2 ESTIMATE OF INCIDENCE AND DURATION OF SICKNESS FOR POPULATIONS EXPOSED TO VARIOUS AMOUNTS OF PENETRATING IONIZING RADIATION

TABLE 1.5

Acute Effects of Ionizing Radiation on Skin

Estimated Dose Required (EDR) in 1 week (rad)	Effect[1]
0-600	No acute effects.
600-2000	Moderately early erythema.
2000-4000	Early erythema before 24 hours. Skin breakdown in 2 weeks.
4000-10,000	Severe erythema in 24 hours. Severe skin breakdown in 1 - 2 weeks.
10,000-15,000	Severe erythema in 4 hours. Severe skin breakdown in 1 - 2 weeks.
15,000-100,000	Immediate skin blistering (< 1 day).

(1) For exposures extending over a period of more than a few hours, the temporal relationships will be modified somewhat from those shown. For example, a dose of 4000 - 10,000 rads given in 1 week will not produce severe erythema in 24 hours.

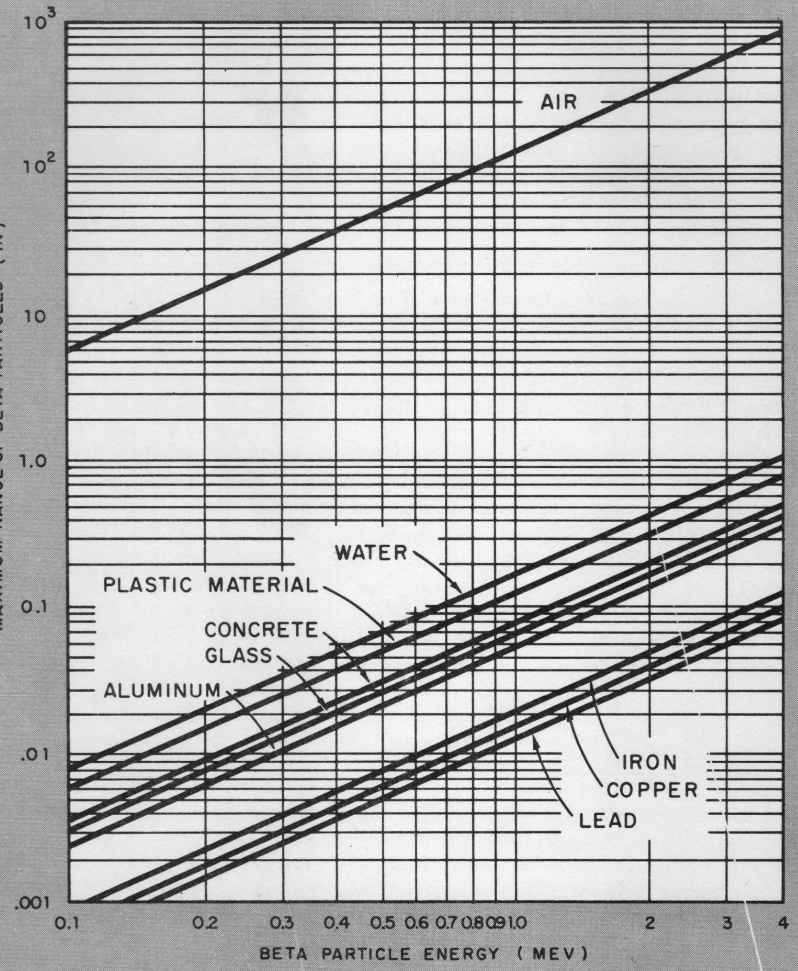


FIG. 2.5 PENETRABILITY OF BETA RADIATION

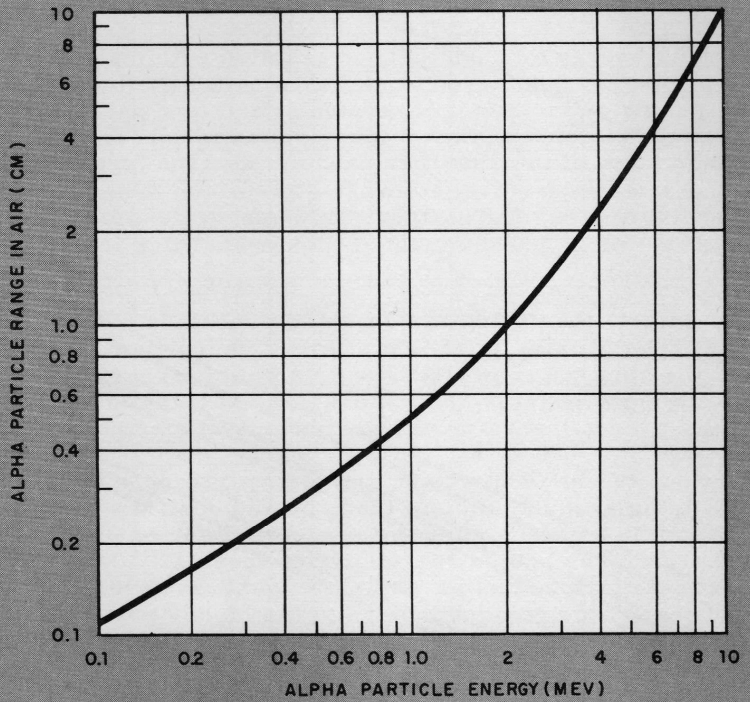


FIG. 2.6 MEAN RANGE OF ALPHA PARTICLES IN AIR

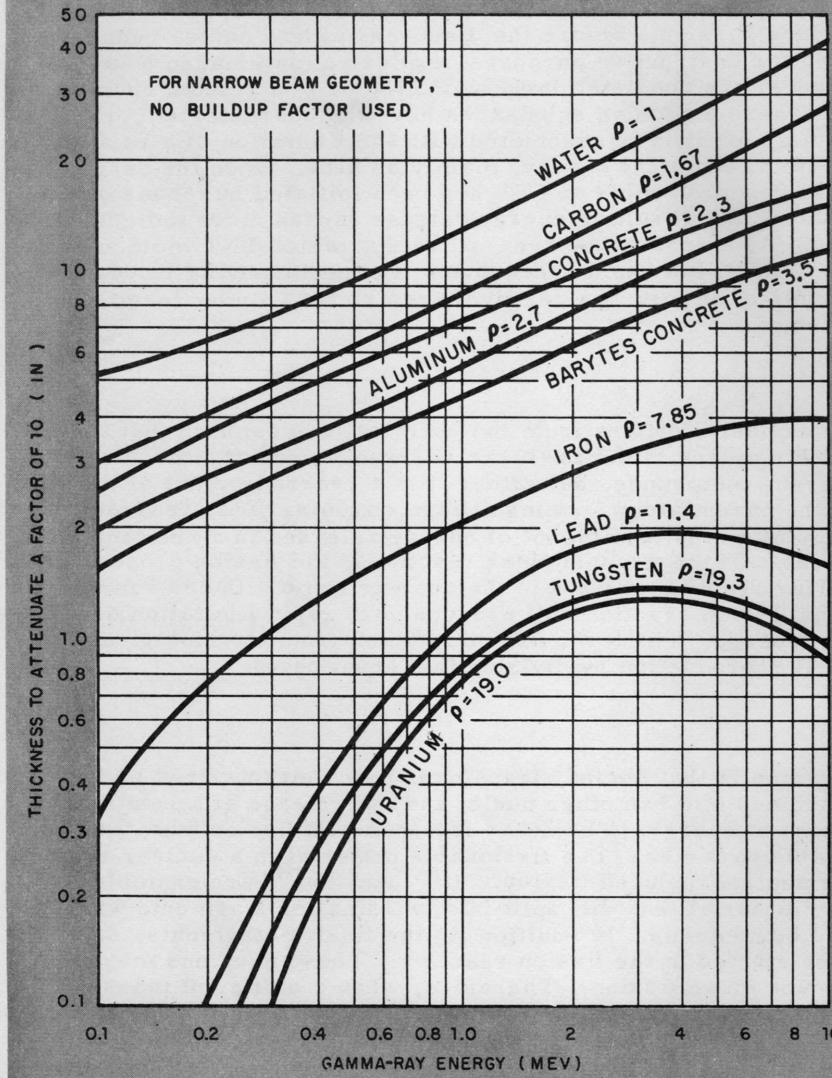


FIG. 2.8 TENTH-VALUE THICKNESS FOR GAMMA RAY ABSORPTION

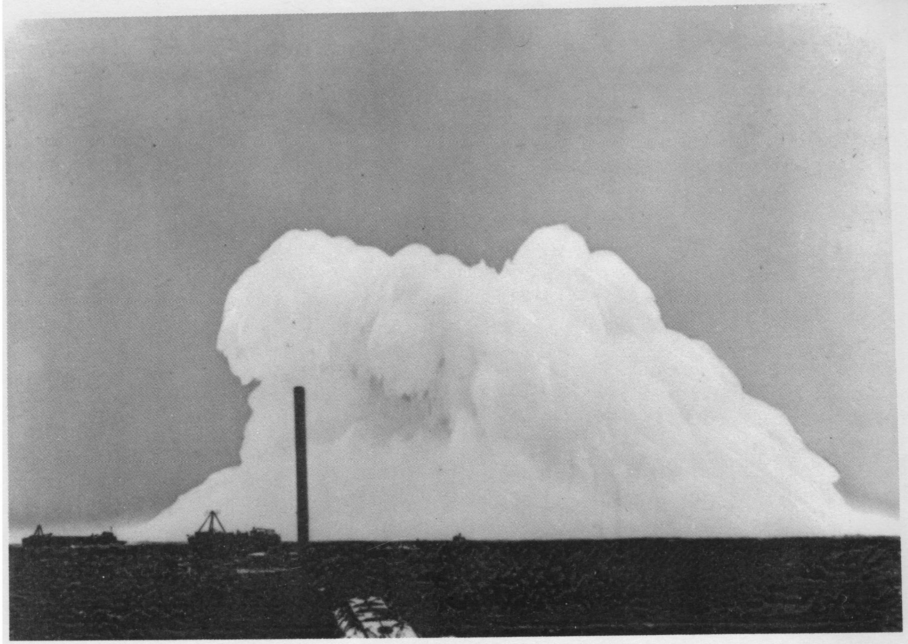
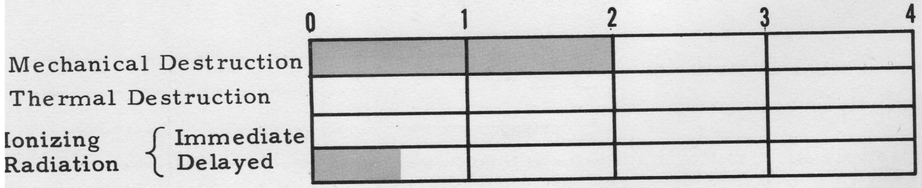


FIG. 2.18 DEEP UNDERWATER BURST



In a deep underwater burst, Fig. 2.18, the fireball forms a hot gas bubble consisting of the bomb detonation products, plus large quantities of steam. This bubble, in rising to the surface, pulsates, and, in so doing, loses some of its radioactivity in deep layers. To what extent it retains its ident ty as it approaches the surface is not known but, in these circumstances, there is no large cylindrical column of water and no well-defined visible "atomic cloud." A large fraction of the radioactivity is contained in the foam or froth in a circular region directly above the detonation point. There appears to be no extensive fallout, but the drifting mist may be dangerously radioactive within a few miles of SZ. Also the deposition of highly radioactive foam on a nearby shore would be hazardous.

Table 3.1

Dose Rate from 1 Curie of Co^{60}, Cs^{137}, and Ra^{226}

Isotope	Half-Life	r/hr at 1 ft	r/hr at 1 meter
Co^{60}	5.2 yr	14.3	1.32
Cs^{137}	30 yr	3.83	.356
Ra^{226} in equilibrium with decay products	1620 yr	Filter	
		Thuringian Glass	0.93
		0.5 mm Pt-Ir	0.84
		1.0 mm Pt-Ir	0.78
		Each mm of lucite reduces the gamma output by 0.35%.	

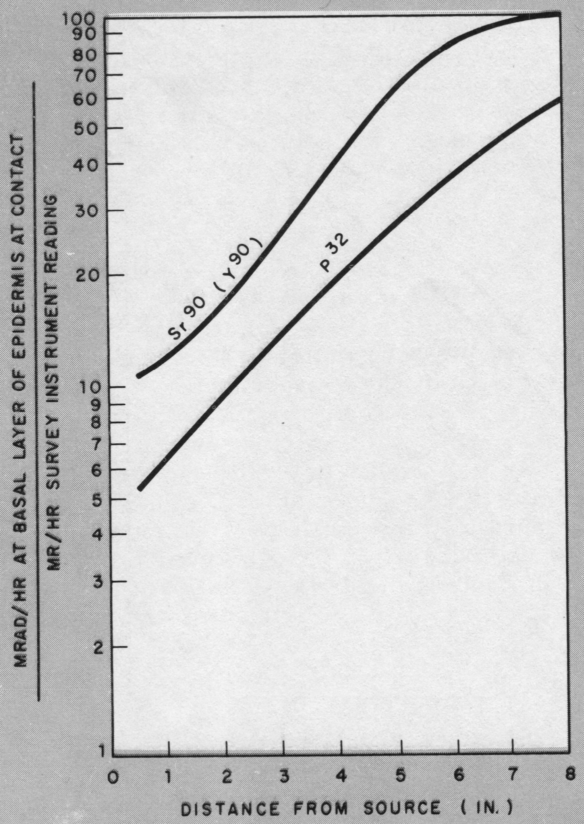


FIG. 3.16 RATIO OF CONTACT DOSE RATE AT THE BASAL LAYER OF THE EPIDERMIS TO SURVEY INSTRUMENT READING AS A FUNCTION OF SOURCE-TO-SURVEY-INSTRUMENT DISTANCE.

Type Instrument: CDV-700 G-M Type Radiac.

Table 3.2

Dose Rate vs Distance From 500 mg Ra Source

Calculated Dose Rate (mr/hr)	Distance (cm)	Measured Dose Rate (mr/hr)	Correction Factor
25,000	13.0	22,000	1.14
2,500	41.2	2,300	1.08
250	130	300	0.84
25	412	21	1.19
2.5	1304	3	0.84

(Meter Reading) x (Correction Factor) = Dose Rate

Gamma: The exposure dose rate from a gamma point source may be approximated to within 20% by the formula:

$D_1 = 6\,C\,E$, where

D_1 is the dose rate in r/hr at 1 foot from the source

C is the number of curies

E is the sum of all the gamma emissions of the isotope per disintegration in Mev.

Dose Rate in an Infinite Absorbing Source Material

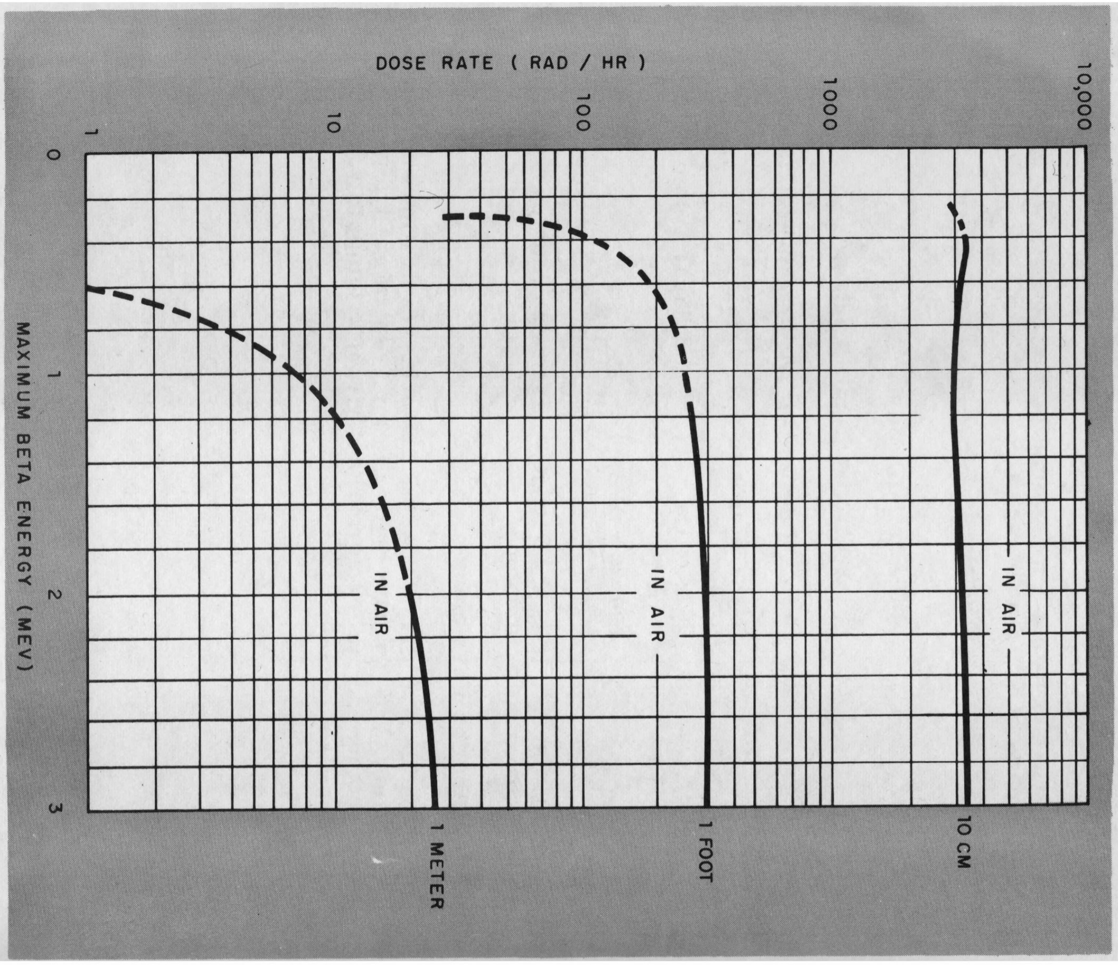
For a source uniformly distributed throughout an infinite absorbing medium, considerations of the conservation of energy lead to the relationship:

$D = 2.30\,C\,E$, where

C is the specific activity of the source in μc/gram,

D is dose rate in rads/hour,

E is the mean energy per disintegration in Mev.



(Note: Beta energy is maximum of spectrum; mean energy is assumed to be one-third of maximum.)

FIG. A-1 DOSE RATE FROM POINT BETA SOURCE OF STRENGTH 1 BETA CURIE

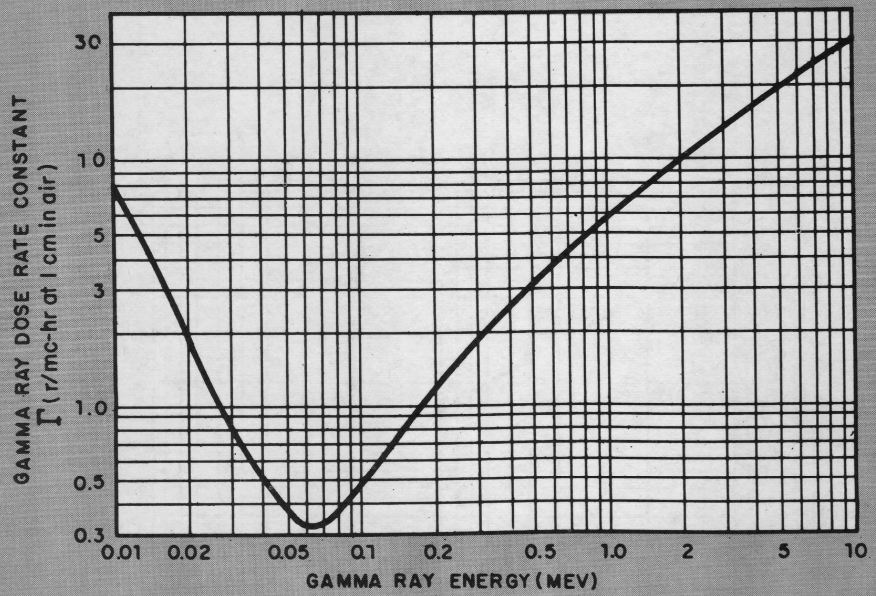


FIG. A-2 GAMMA RAY DOSE RATE CONSTANT, Γ (r/mc-hr at 1 cm), FOR A POINT SOURCE IN AIR AS A FUNCTION OF GAMMA ENERGY IN MEV

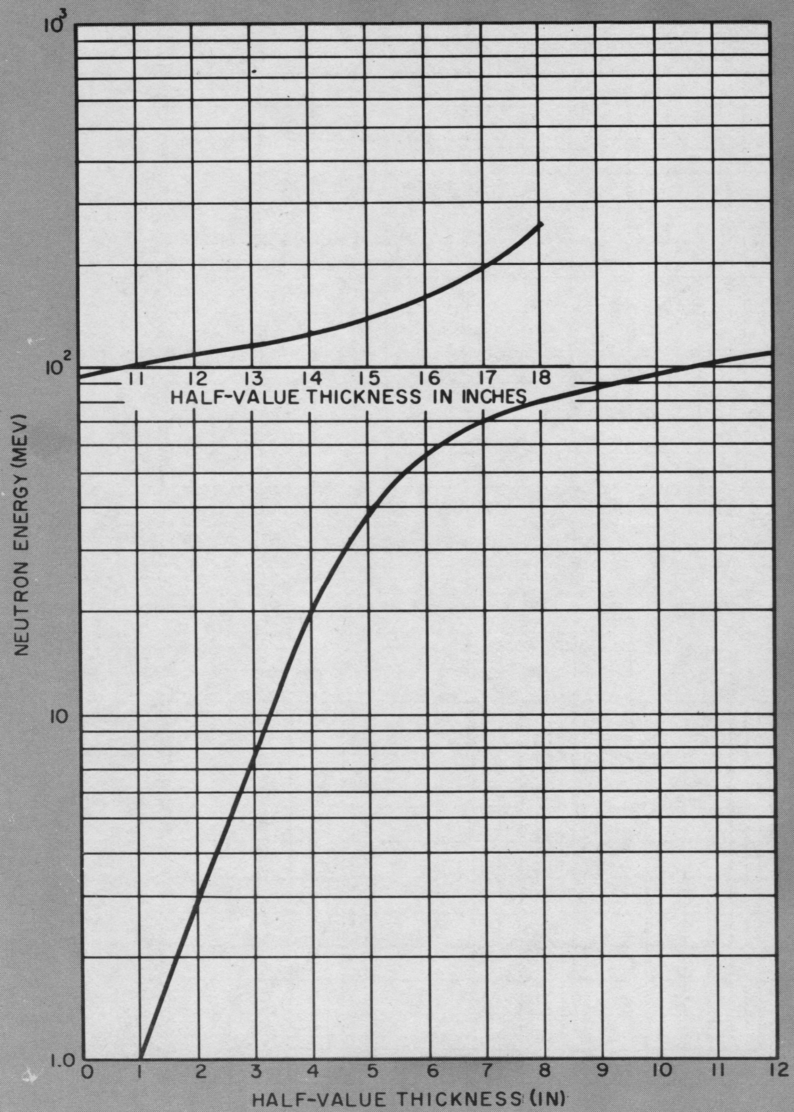


FIG. A-9 HALF-VALUE THICKNESS OF ORDINARY CONCRETE FOR FAST NEUTRONS

TABLE A-I

CALCULATED GAMMA RADIATION LEVELS FOR ONE CURIE OF SOME RADIOISOTOPES[1]

Isotope	Annihilation Radiation	QUANTUM ENERGY (E) IN MEV — Nuclear gamma radiation (number in parentheses indicates photons/dis)	Dose Rate at 1 Yard (r/hr)	Dose Rate at 1 Meter (r/hr)
Na^{22}	0.51 (2)	1.28 (1)	1.51	1.26
Na^{24}		1.38 (1) 2.76 (1)	2.31	1.93
Mn^{52}	0.51 (0.7)	0.73 (1) 0.94 (1) 1.46 (1)	2.30	1.92
Mn^{54}		0.84 (1)	0.54	0.45*
Fe^{59}		0.2 (0.03) 1.1 (0.57) 1.3 (0.43)	0.77	0.65
Co^{58}	0.51 (0.3)	0.81 (1)	0.67	0.56*
Co^{60}		1.17 (1) 1.33 (1)	1.59	1.32
Cu^{64}	0.51 (0.38)		0.137	0.114
Zn^{65}	0.51 (0.04)	1.12 (0.47)	0.36	0.30*
I^{130}		0.417 (0.4) 0.537 (1) 0.667 (1) 0.744 (1)	1.48	1.23
I^{131}		0.080 (0.063) 0.284 (0.063) 0.364 (0.809) 0.637 (0.093) 0.722 (0.028)	0.276	0.231
Cs^{137}		0.661 (0.92)	0.426	0.356
Ir^{192}		20 known lines 0.136 to 1.157 Mev	0.61	0.51
Au^{198}		0.411 (1) 0.68 (0.013) 1.09 (0.0025)	0.297	0.248
Ra^{226} & equilibrium decay products		Many known lines	1.005**	0.84**

* Isotopes have X-ray emission following electron capture whose contribution to I is negligible at 1 meter but would not be at distances of the order of 1 cm. Self absorption is ignored.

** With 0.5 mm Pt filter. This figure is the average of better measurements.

1 Excerpt from Radiological Health Handbook PB 121784, U. S. Dept. of Public Health, Education and Welfare, January 1957.